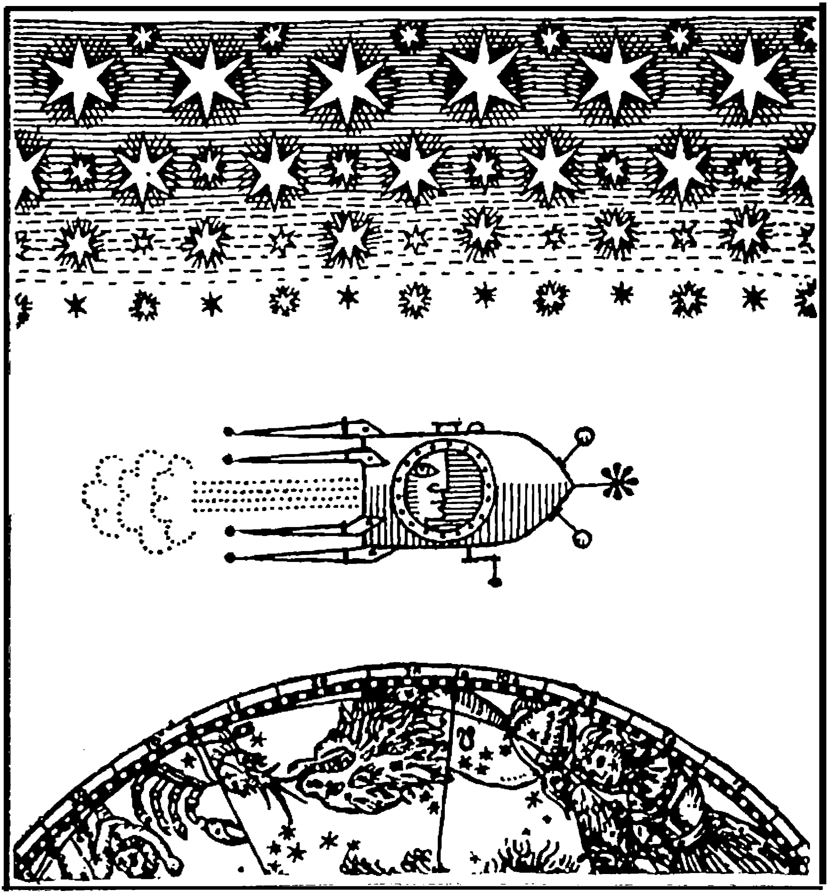
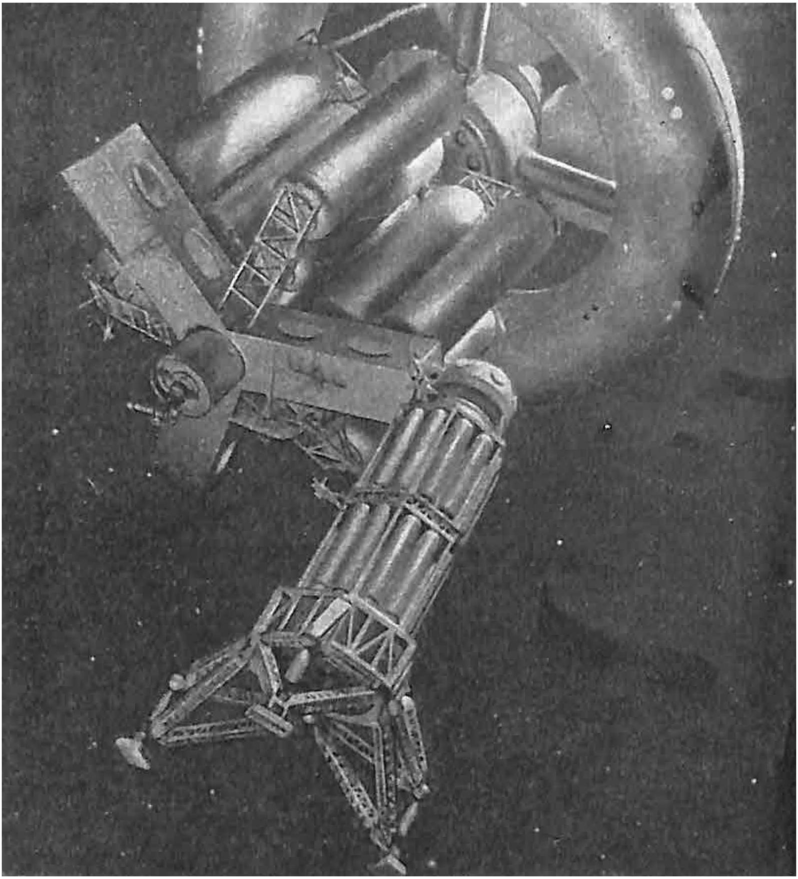


Outer Space and Man

MIR
PUBLISHERS



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OUTER SPACE AND MAN

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Translated from the Russian
by
Vladimir TALMY

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ABOUT THIS BOOK

This book has appeared now for the very reason that it didn't appear 20 centuries or half a century ago—because of speed. Jules Verne's *Around the World in Eighty Days* required a speed of 500 kilometres a day. *Outer Space and Man* requires escape velocity at least.

Before the reader embarks on this book we should like to give him a warning. It has several qualities which, if not mentioned in advance, may escape his attention, and he may not like the book so much—which would be a pity.

We hope that this book will be easy to read. We should like the reader to smile occasionally and to stop and think occasionally, but never to wrinkle his brow trying to recall some forgotten textbook formula. We know that no one has tried to define cosmic humour, but we have seen Gagarin's smile and we make so bold as to claim that if people didn't know how to laugh they would never have entered outer space.

But this is not a funny book. It has no formulas, but it does have numbers. It has words like "orbit", "parsec", and even "explosive decompression". When it was finished all the authors and editors reread it, and each one understood many things, and all together they understood everything. In any case, the reader will probably realize that outer space is not to be trifled with.

The book is far from comprehensive. Many things have not been reflected, described or even mentioned. But why speak of omissions? If it contained everything about outer space it would be another kind of book which we should be unable to judge.

When the authors got down to work they knew of only two Soviet cosmonauts. By the time they had finished there were eleven. The ink will dry on the printed pages, the reader will get to the last part and then how many will there be?

We can only guess how many new cosmonauts there will be and what new exploits they will have performed.

Per aspera ad astra—through difficulties to the stars—the ancients used to say. They prayed humbly to their gods and dreamed meekly of heaven.

Hey, you,
    Heaven,
        Take off your hat!

This is the voice of the 20th century.

A century of dazzling heights and breathtaking speeds.

Of astounding breakthroughs in science and technology.

Of great social revolutions.

And it is hardly accidental that the people who created a new world on earth were the ones to blaze the trail into the unknown, into outer space.

The stars look down—attentively, watchfully, expectantly.

Who knows what they will yet witness?!

★ I ★

There was a many night and day
Ere ever thou and I were born:
And still the spinning skies are sworn
To persevere upon their play.

OMAR KHAYYAM

A THOUSAND MILLION CENTURIES

A miser knelt in prayer:

"Oh, Lord, you are great and omnipotent! What is a thousand years to you?"

"But an instant."

"What are a thousand ducats to you?"

"But a penny."

"Well, give me that penny."

"All right. Wait an instant."

According to this time scale, the Biblical creation of the world took place 5.5 instants—or, to be more precise, 5,508 years—before the birth of Christ (one theologian is even reputed to have specified that it happened in the early hours of the last Monday in October).

Today problems concerning the creation and age of the world are no longer the concern of story-tellers, whether lay or clerical, but of the flourishing science of cosmogony (to say nothing of the cartoonist Jean Effel).

The sun takes more than 200 million years to make one orbit round the centre of the galaxy of the Milky Way. This is a sort of galactic year. One "year" ago the Mesozoic era, the age of the dinosaurs, existed on earth. Man is not more than two "days" old. A human life is but a few "seconds". Can one hope to gain a knowledge of centuries—galactic centuries—in these few seconds?

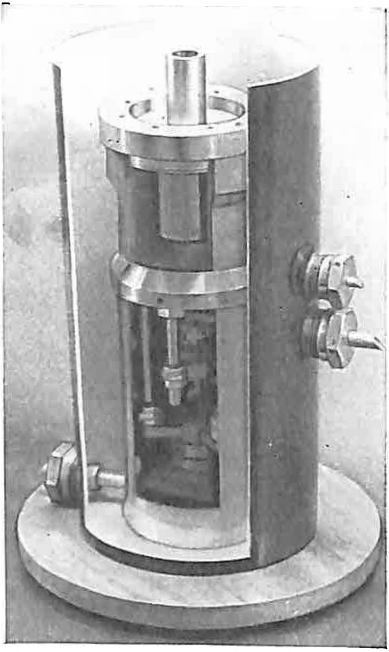
> Nature does not know the past,
> Our fleeting years are nothing to her.

Nature doesn't know, but man wants to know everything. He reads the book of the heavens, where the past and future of the universe are recorded in great detail. The infinite expanses of outer space are populated with young stars and old planets, with budding, ripe, middle-aged and dying suns. They demonstrate thousands of times over and over again the evolution of our own sun and earth and other worlds. Thousands of millions of years lie unfolded in outer space. The great story of creation is inscribed there. Man has but to learn to read it.

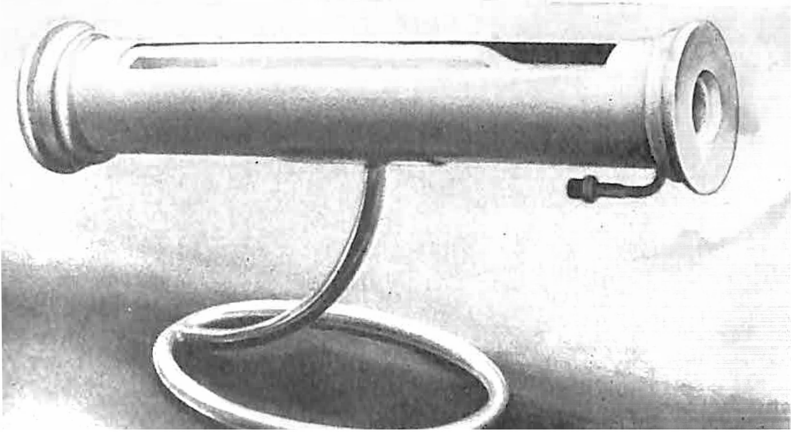
ONLY HYPOTHESES

The first, highly unscientific, hypotheses about the origin of all things were enunciated some 500 centuries ago.

Konstantin Tsiolkovsky, eminent scientist who developed the theory of rocket flight 60 years ago



Beginnings of cosmonautics: the first Soviet rocket engines of the early 30s



The first scientific hypotheses of the origin of the sun and its attendant planets are barely two centuries old. They were put forward by Kant and Laplace, who postulated that the solar system had originated out of a highly rarefied rotating nebula. According to Kant, it was made up of tiny particles; according to Laplace, it was a gaseous cloud which cooled and contracted. As it contracted it rotated faster and faster, throwing off successive rings of matter, which later coalesced into planets.

Kant's and Laplace's hypotheses held their own for almost 150 years before they were declared untenable. Recently, however, Laplace's theory has been revived.

The German scientist Weizsäcker has put forward a theory according to which the sun once passed through a cloud of dispersed interstellar matter, capturing some of it. Vortices appeared in the cloud, and the planets and their satellites formed from them. The American Harold Urey suggests that the primordial cloud from which the solar system later evolved was at first cold. Then condensations appeared, and the largest one gradually warmed up and became the sun. The sun heated the lesser condensations round it, and these turned into the planets and their moons. The surface temperature of the planets was at no time higher than 2000°C. Later they cooled down to their present temperatures.

The Soviet astronomer Vladimir Fesenkov has another theory: many thousands of millions of years ago the mass of the sun was much greater than now, and it rotated much faster, throwing particles of dust and gas into the surrounding space. Later, condensations appeared in the cloud which became the planets. An analogous theory was suggested by the American astronomer Gerald Kuiper.

Otto Schmidt, the eminent Soviet mathematician and traveller, put forward a theory according to which celestial bodies are formed from the accretion of cold, solid particles. The earth and other planets were at first cold. Subsequent radioactive decay inside the earth caused it to warm up.

The stars continuously radiate and eject vast quantities of energy. The process could not be sustained by conventional chemical combustion; estimates indicate that if that were the case stars would cool within a few million years. They are kept hot by thermonuclear reactions (the nature of which has not yet been completely explained): hydrogen "burns away" into helium and, under certain conditions, into carbon, oxygen and other elements. These huge heat factories are at the same time factories making chemical elements.

In the nineteen-forties, the Soviet astronomer V. A. Ambartsumyan discovered stellar groups or clusters whose component parts appear to be flying apart. Within several tens of millions of years such a cluster will disperse altogether. The apparent conclusion is that stars originate in "batches", and that the process is continuing to this day. Our sun, too, must have gone through some such stage in its evolution.

But how do young stars appear? Many astronomers hold that they develop out of dense accumulations of cold gas and dust, stars and glowing nebulae forming simultaneously. Young stars (a few hundred or a thousand million years old) are represented by hot giants of low luminosity. When an appreciable portion of a star's hydrogen has burnt away and is replaced by helium, old age sets in. According to a theory of the American astronomers M. Schwartzschild, A. Sundage and others, they increase in size and luminosity, turning into red giants. At this evolutionary stage the star's helium starts burning and produces the heavier elements. Later the star's outer layer is ejected into space and dispersed as gas, leaving a small but extremely dense nucleus; a white dwarf, the veteran of stellar populations.

SIZING UP THE UNIVERSE

Our globe is a flat in the third storey of a house which we call the solar system. The house is located in an outlying part of a vast stellar community numbering some 150,000 million stars. It takes a beam of light 80,000 years to cross this community from end to end. Scattered about us in space are many near and distant communities called galaxies, which are great concentrations of stars. Our galaxy is lens-shaped. Viewed "from above" it looks like a vast spiral; seen edge-on it is spindle-shaped.

The Milky Way stretching across the sky is our galaxy seen edge-on. Towards its centre, 25,000 light years away from us, the stellar population grows denser and denser. The solar system revolves around the centre at a speed of 250 kilometres per second.

Several centuries ago a great nebula was discovered in the constellation of Andromeda. But the fact that it is not a gaseous nebula but a stellar system very much like our own galaxy was established only 40 years or so ago. The Andromeda Nebula is a neighbouring stellar community about two million light years away.

Other systems like the Milky Way have been discovered in the constellations Ursa Major (The Great Bear), Canes Venatici (The Hunting Dogs), Triangulum (The Triangle) and many others. At first observers thought that all stellar systems were essentially similar to the Milky Way. However, the farther telescopes penetrated into space the greater the diversity was found to be. There are galaxies which from afar look like fantastic insects with huge antennae made up of millions of stars; there are galaxies trailing vast tails and galaxies connected by filaments of stars. One galaxy in the constellation Canes Venatici is very like the Milky Way, but at the end of one of its spiral limbs there is a big lump. It turned out to be two galaxies joined by a stellar "filament". Other galaxies are connected by filaments tens of thousands of light years long. One cluster of galaxies is immersed in clouds of glowing gas in which lone stars are seen to be travelling from one stellar "community" to another.

Neighbouring galaxies must, apparently, interact. Some of these interactions are so remarkable and unusual that eminent astrophysicists are baffled. Two galaxies represent two great masses. Newton's tried and tested law states that they must mutually attract each other. If only that were the case! Many galaxies refuse to obey Newton's law. Pairs of galaxies have been discovered in which forces of repulsion appear to dominate the forces of gravitation. What is the cause of this? What is the nature of these forces? No one knows.

Galactic systems radiate vast quantities of light energy and radio waves, usually weak, in all directions. But some galaxies are powerful sources of radio waves. The closest radio galaxy, Centaur A, is some 15 million light years away. On the other hand, emission from one of the most powerful radio sources, the galaxy Cygnus A, reaches us 600 million years after it was generated.

Astrophysicists are closely studying galactic nuclei where, they assume, the answers to most of the galactic riddles are to be found. How, when, and why did galactic systems originate?

The nucleus of the Milky Way has been found to be continuously ejecting matter at a rate of one solar mass a year. The same is true of the nucleus of the Andromeda Nebula and many other stellar systems. The nature of galactic nuclei is still a mystery, but it appears that they are actually spewing out millions of worlds. In 1963, astronomers discovered supergiant radio stars. Called quasi-stellar radio sources, or quasars, they are estimated to have masses hundreds of millions of times that of the sun. Obviously they are much too big to be regarded as stars. But they may represent em bryonic galactic nuclei which in several million years will become fully-fledged radio galaxies.

Hundreds of galaxies, thousands of galaxies, and millions of galaxies. The farther away they are the greater the displacement of their spectral lines towards the red end of the spectrum. This phenomenon, known as the Doppler effect, indicates that the more remote a galaxy the faster it recedes from us. Recent measurements of a galaxy 6,000 million light years away indicate that it is receding at a velocity of 140,000 km/sec, almost half the speed of light. Or, to be more accurate, that was its speed long before the earth was born. Man will know its present state of affairs only in 60 million centuries.

If a galaxy is likened to a stellar community, what then is a stellar "nation" and a stellar "hemisphere"? It has been found that many galaxies, including the Milky Way, appear to be part of a greater "metagalactic" system. This, at least, is the conclusion reached so far by the arrogant little creatures inhabiting a tiny planet near a diminutive yellow star in one of the commoner galaxies.

CELESTIAL MECHANICS

Nature is secretive. Its laws are coded, sealed and hidden away in formidable strong-boxes. It reveals its secrets most reluctantly, often giving explorers mere substitutes for the truth. Time and again scholars have had to revise notions which seemed to be sound and self-evident. The ancient Greek astronomer Ptolemy was convinced that the earth was the centre of the universe, and the sun, Mars, Venus and the other planets were its satellites. His ideas reigned supreme for 14 centuries, until the genius of Copernicus and the courage of Giordano Bruno gave the sun its rightful place in our system. In the 16th century many men spent night after night studying the stars in the sky. Hundreds of astrologers studied the motions of the planets. Columns of numbers and networks of diagrams covered countless sheets of paper, and the best minds of the Middle Ages sought to detect the laws behind the avalanche of information.

One of the most remarkable men in the history of science, Johannes Kepler, devoted his whole life to this task. He was half blind, and could only view the skies through the eyes of other men, but this did not prevent him from earning the title of "lawmaker of the heavens". Again and again he plotted the mutual positions of the earth and sun on a diagram in an attempt to discover the formula of the earth's orbit. The orbit looked like a circle, but the sun appeared to be displaced from its centre. Kepler turned to Mars in an attempt to make that planet follow a circular orbit. To his disappointment Mars, too, refused to move in a circle. He wrote:

> I was preparing to celebrate my victory over Mars, when suddenly my fortunes suffered a reverse. The war continues as fiercely as before. The perfidious enemy in the sky

> suddenly broke the chains of my equations and escaped from the prison of my tables. In a number of forays he defeated my legions of physical causes, cast off my yoke and escaped to freedom.

Kepler, however, was a persevering man, and he stubbornly laid siege to the red planet until it finally surrendered the secret of its motion. The orbit of Mars turned out to be an ellipse, a flattened circle.

A circle has one remarkable point, its centre. An ellipse has two such points, its foci. The more an ellipse is elongated the farther apart are its foci. The closer its foci, the more the ellipse resembles a circle. In Kepler's diagram the sun lay at one of the foci of the orbit of Mars. It was probably then that the great idea occurred to him that the earth, too, must be moving in an ellipse, but an ellipse which was very nearly circular. And Kepler formulated his first law: *All planets follow elliptical orbits with the sun located at one of the foci.*

He also found that the planets move in their orbits with varying speed. After long and painstaking calculations Kepler made a brilliant discovery. He found that if a straight line is drawn from a planet to the sun, this line will always sweep over equal areas in equal intervals of time. Astronomers call this area a planet's sectoral velocity, and Kepler's law can be formulated as follows: *A planet's sectoral velocity is constant.*

Kepler's first two laws are applicable to individual planets. His third law establishes a connection between the motions of different planets. Obviously it must take a more distant planet longer to circle the sun than a closer planet. How much more? *The squares of the periods of revolution of different planets around the sun stand in the same ratio as the cubes of their mean distances from the sun.*

Now we know *how* planets move. But what causes them to move? Already Leonardo da Vinci, Copernicus and Kepler had surmised that bodies gravitate towards one another, and that the forces that make a stone fall to the ground are essentially of the same nature as the forces acting between celestial bodies. It took years and years of intense work by Galileo, Borelli, Hooke and many other scholars before Isaac Newton could finally, towards the close of the 17th century, enunciate his "universal law of gravity" according to which *all material bodies attract each other with a force directly proportional to their masses and inversely proportional to the square of the distance between them.*

It would be natural to ask why the planets don't fall into the sun. The answer is that they are falling! But the trajectories are closed into ellipses. It is as though the planets were "missing" the sun all the time. It is all a question of the magnitude and direction of the velocity. If the velocity of a planet (or any other body in interplanetary space, for that matter) is small enough, it will fall into the sun.

Almost 300 years have passed since these laws were discovered, and the science of celestial mechanics has progressed enormously, but still the laws of Kepler and Newton are amongst its most brilliant achievements.

HOW EMPTY IS SPACE?

An author of popular science stories once received a letter. "How can you speak of the bitter cold of outer space?" an irate reader asked. "For if it is a vacuum, a void, there are no atoms or molecules, and without them it is meaningless to speak of temperature. Any high-school physics textbook will tell you that."

Although for all his knowledge of physics the reader was mistaken, the author nevertheless felt that he too was at fault. There are hardly any articles devoted to space travel which do not mention "the cosmic void" or "the vacuum of outer space". Are these expressions correct?

The answer is, yes and no. Yes, insofar as outside the planetary atmospheres there is no water or any other liquid, and solid matter, as represented by meteorites and dust, is so scarce as to be discounted. And yet interplanetary space is not absolutely empty. In the neighbourhood of the earth's orbit every cubic centimetre of space contains, on average, more than 100 molecules of gas. This is not much, especially if we remember that the density of air in a thoroughly evacuated vacuum tube is incomparably higher. Still, it is not a vacuum and for all practical purposes the planets can be said to be floating in the sun's atmosphere. The extremely rarefied corona of the sun, consisting mainly of free electrons, extends to Pluto and beyond.

Dust and small and big meteorites should not be neglected either. The amount of dust in outer space is much greater than was originally presumed. It was established not long ago that the well-known phenomenon of zodiacal light, which is a faintly luminous band extending along the whole length of the ecliptic (it is seen as a night glow in the plane of the constellations of the Zodiac), is due to the reflection of light by particles of cosmic dust.

Outer space is also traversed by streams of visible light, gamma rays, X-rays, ultraviolet and infrared rays and radio waves, all of which are as tangible manifestations of matter as stone or water or air. All these types of electromagnetic radiation can be likened to a shower of minute particles called photons.

There are also appreciable magnetic fields and fields of gravity emanating from planets, stars and galaxies. The whole of space is pierced in all directions by cosmic rays, which consist mainly of fast nuclei of hydrogen, helium and such heavier elements as iron and nickel.

April 1, 1964, marked the beginning of the International Year of the Quiet Sun, a worldwide effort in scientific cooperation. Up to the end of 1965, solar activity was at a minimum and the solar system was especially transparent to rays from the depths of the Milky Way.

In other words, outer space is far from empty and there is nothing wrong in speaking of its temperature. More remarkable is the proximity of cold and heat in space. The shaded part of a space ship flying, say, to Venus will cool down almost to absolute zero while the side turned to the sun will be heated by its rays to an appreciable temperature. In short, the "void" of outer space is full of surprises.

THE YELLOW DWARF

It may come as a shock to some people that our great life-giving luminary is a very undistinguished star of spectral class G, a yellow dwarf located in a rather sparsely populated region of a very common galaxy. Our sun is indeed a dwarf compared to the red and blue giants which, in its place, would reach out to the orbit of Saturn.

Incidentally, in ancient times the sun was thought to be really dwarf-sized, and scholars argued only whether it was the size of a millstone, a chariot or, possibly, as big as Athens. The sage who made so bold as to suggest that it was at least as big as the peninsula of Peloponnesus was banished in disgrace.

Equally vehement arguments raged around the question of the distance to the sun. The summit of Mount Olympus towers three kilometres above sea level, but obviously the heavenly bodies could not be higher than the gods. The courage of the medieval monks who moved the sun several dozen miles higher was truly remarkable. To be sure, some mortals, like Aristarchus of Samos and Hipparchus of Nicaea, disturbed the peace of mind of devout citizens by speaking of millions of miles. But then, who would believe them?

Two thousand years later the great "sun worshippers" Copernicus, Giordano Bruno, Galileo and Kepler knew which heavenly body orbited which, but they were ignorant as to the actual distances separating them.

Only towards the end of the 17th century did Cassini calculate the distance with any accuracy at all; he set the sun at 140 million kilometres away. Two centuries more passed before the distance was increased to 149,500,000 km.

A dazed humanity was asked to swallow the idea that the sun was a huge ball of fire 1,300,000 times bigger than the earth and 745 times heavier than all the planets put together; that it ejected fiery prominences to heights exceeding the distance from the earth to the moon; that the sun had "cool" spots in which the temperature was high enough to vaporize the most refractory metals; and that the mean surface temperature was 6000° Celsius.

Every minute the sun ejects, radiates and loses for ever 240 million tons of matter. For thousands of millions of years the earth has been receiving all the energy it needs to sustain life on it. Yet we need not fear that the supply will run out; it will take 150,000,000 million years for the mass of our little yellow dwarf to decrease by one per cent.

Beneath the sun's surface the temperature is in millions of degrees, and the workings of the gigantic nuclear reactor inside are still largely a mystery. The accepted hypothesis is that hydrogen is being transformed into helium, as in a hydrogen bomb.

Solar activity follows a regular eleven-year cycle in which the prominences and sunspots increase and decrease, causing corresponding fluctuations in magnetic storms and spectacular auroral displays in planetary atmospheres.

Our star is a relative youngster, probably not more than 10,000 million years old. It contains 999/1000ths of the total mass of the solar system, and is hurtling through space at a velocity of 250 km/sec. While you have been reading these pages the sun has taken the world several tens of thousands of kilometres from the place where it was when you began. It will come back to the same place one day—in somewhat more than 200 million years from now.

THE SUN'S PET

The giant disk of the sun, looking seven times larger than it does on earth, never leaves a black sky. The temperature is always 400° C above zero. But this is only on one half of the planet. On the other side there is eternal darkness and 270 degrees of cold.

This small (1/14th of the earth's volume and 1/25th of its mass), fast planet was named Mercury in honour of the wily Roman god of commerce, eloquence, cunning and theft. The Mercurian year lasts 88 terrestrial days. Mercury is so close to the sun (from 46 to 70 million kilometres) that it can be seen with the unaided eye only shortly after sunset or before sunrise.

Only the boldest of science-fiction writers have undertaken to populate Mercury with intelligent beings, despite the fact that in addition to its other extremes, there is practically no atmosphere on the planet.

Mercury is not all that far from the earth; only 250 times farther than the moon. The force of gravity at the planet's surface is one-quarter that of the earth. Maps have been drawn of its daylight side and several large spots, evidently lowlands, can clearly be seen.

Future astronauts will find that Mercury resembles the moon: no atmosphere, large temperature extremes and low gravity. Its surface is probably also pockmarked like the moon's. Conquest of the moon, when it begins, will certainly provide an excellent testing ground for preparations for subsequent voyages to Mercury. Meanwhile Mercury has been used to bounce radar beams back to earth.

There are certain irregularities in Mercury's motion round the sun which so far defy explanation. Some scholars suggest that there may be a planet between Mercury and the sun which cannot be observed because of the latter's bright rays. It has even been named Vulcan, but no reliable proof of its existence has so far been obtained.

BEHIND A VEIL OF CLOUDS

This is the nearest large planet. Its minimum distance from the earth is 39,000,000 kilometres, only several months' rocket flight away. It is the second brightest luminary (after the moon) in the night sky and is 13 times more brilliant than Sirius, the brightest star. This would appear to make it the most accessible for observation and study from the earth. However, the world named after the beautiful goddess Venus is as secretive as it is close and brilliant.

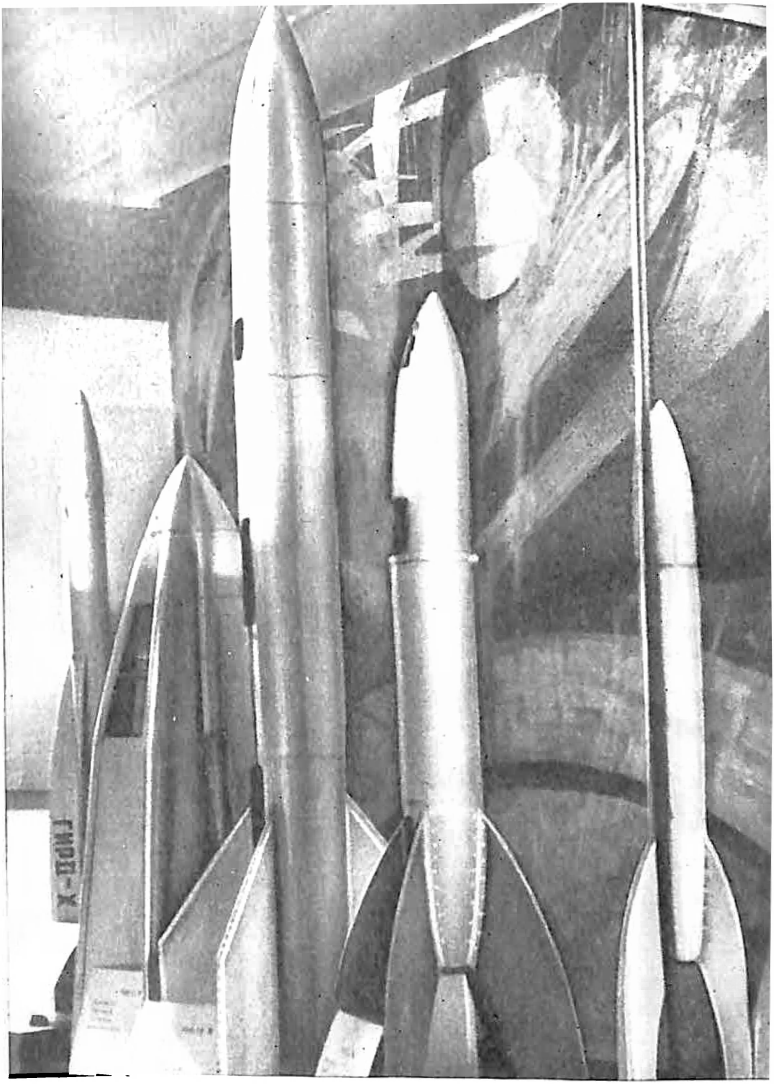
To begin with, the brightest planet in the sky had actually to be discovered and accounted for, and Pythagoras is credited with having proved that the sparkling evening star and bright morning star known to all were actually one and the same heavenly body.

In 1610, Galileo discovered that it displayed phases like the moon.

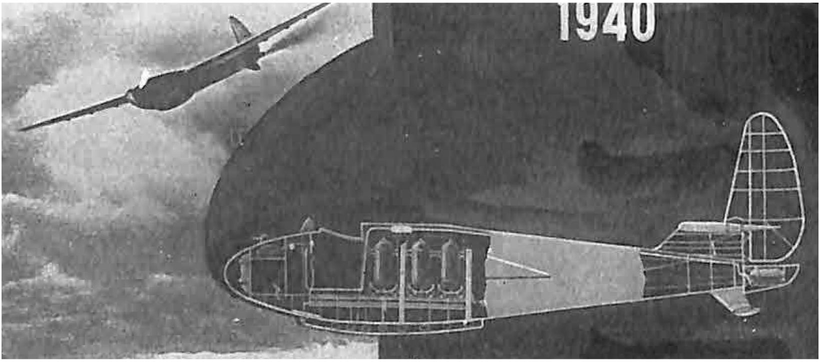
In 1761, Lomonosov observed the transit of Venus across the sun's disk. He wrote:

> A bump appeared at the edge of the sun, which became increasingly apparent as Venus prepared to leave the disk. Then the bump disappeared and Venus suddenly resumed its shape.
>
> Lomonosov explained the observed irregularity in the visible limb of the sun's disk by the fact that "the planet Venus is surrounded by a substantial gaseous atmosphere . . . like that which envelopes the terrestrial globe."

Thus the Venusian atmosphere was discovered. As observation techniques improved over the following two centuries many a venerable scholar was deprived of his peace of mind. One of the first victims was the thorough and deliberate German astronomer Schroeter, who announced the discovery of great mountains on Venus. His "discovery", however, was soon



Precursors of the Vostoks and Voskhods, which were built by a group of enthusiasts



In 1940, the first gliders with rocket boosters were flown proved wrong by the Englishman Herschel. The "mountains" turned out to be a freak of the planet's atmosphere, a dense, impenetrable envelope of clouds of which we can only see the outermost layer.

Today astronomers are attacking the Venusian atmosphere with giant optical and radio telescopes, radar and spectroscopes, from the earth, aircraft, balloons, artificial satellites and interplanetary probes. Nevertheless, the science-fiction authors continue to let their imaginations run away with them, and many have forsaken Mars, which is too clearly observable, in favour of the secretive Venus.

Today all we know about Venus is that in size it is virtually the earth's double (0.99 of the terrestrial diameter) and that the Venusian year is 225 days long, 2/3 the terrestrial year. As to the length of the day, that is the time taken for the planet to make one revolution on its axis. views range from as little as 22 hours to as much as 225 days.

The average distance of Venus from the sun is 108,100,000 kilometres, and accordingly it receives 2.5 times more solar energy than the earth. No one knows whether there are any seasonal changes on Venus. This depends on the angle of inclination of the planet's rotational axis, which is not known for sure. If we are to believe some scientists, it is very like that of the earth. If this is so, then, of course, the seasons must change; if not, then summer reigns eternally in some zones and spring in others.

The list of things we do not know about Venus includes the atmospheric pressure at the surface. According to some estimates it is ten times greater than on the earth. If that is so, it means that even at 170° C water does not boil there.

Scientists are giving special attention to the search for water and oxygen, the two indications of life of a "terrestrial type", in the Venusian atmosphere. So far carbon dioxide has been detected in large quantities, as well as traces of some unknown substance. There seems to be no water vapour or oxygen, though the latest reports indicate that they may still be found there.

According to one theory, Venus has no great open bodies of water and most of the planet's oxygen is to be found in its crust. Another theory, however, holds that the whole surface is covered by a primordial ocean, like the earth was thousands of millions of years ago, and plant life has not yet had time to absorb the carbon dioxide and evolve oxygen, as has happened on earth. This explains the abundance of carbon dioxide in the atmosphere.

The eternal shroud covering the face of Venus means that we know less about our closest neighbour than about the most distant stars.

Today the exploration of Venus is conducted along two main lines. One is by means of radar beams reflected from the surface. The second is by interplanetary probes and space ships.

The American space probe Mariner-2, launched on August 27, 1962, passed, 109 days later (on December 14), within 34,800 kilometres of Venus. The probe's instruments collected data and for 42 minutes Mariner's radio transmitter sent information earthwards about the atmosphere and surface. At about the same time observations of Venus continued from earth. Soviet, American and British scientists carried out several series of observations with the help of reflected radar signals. The findings of scientists in that year of active Venusian studies indicated that the neighbourhood of Venus was much less charged with cosmic particles than terrestrial space. Mariner-2 detected no breaks in the mighty cloud cover of Venus and confirmed its slow rotation on its axis. Its report on the temperature of the surface was disappointing, more than 400° C, which would suggest that in all probability the surface of Venus is a burning hot desert. The most important finding, however, was the absence of any perceptible magnetic field.

Some of Mariner's information, for example, about temperature and the absence of a magnetic field, contradicts certain terrestrial observations. Many experts continue to reserve their views, refusing to have faith in the findings of Mariner-2 just because it happened to be 1,500 times closer to Venus than they.

FROM A MARTIAN'S POINT OF VIEW...

"We Martians do not deny that life on Earth is possible, in spite of the highly unfavourable conditions there. Take, for example, its extremely dense atmosphere abounding in that terrible consuming gas, oxygen, which is fortunately so scarce here. The pressure of the atmosphere is such that we should have to keep to an altitude of 15-17 kilometres to feel comfortable. However, at an altitude of 30 kilometres above the surface our own atmosphere is denser than Earth's. The reason for this is the terrible force of gravity on Earth, which would turn a 40-pound Martian into a 120-pound monster. This gravitational pull probably requires the denizens of Earth to have extremely tough skeletons, and a space craft leaving the planet would have to accelerate to more than 11 km/sec, whereas on Mars 6 km/sec is sufficient.

"Our planet is not very big (only one-half Earth's diameter, one-sixth its volume and one-ninth its mass). But, on the other hand, unlike Mars, three-quarters of Earth is covered with water, and Earthmen, if they exist, have less land area than we have.

"It is frequently claimed that Earth is an enlarged replica of Mars. The day is only half an hour shorter, the axis of rotation is inclined at about the same angle and therefore Earth enjoys the seasonal alternations of spring, summer, autumn and winter (though of half the duration of our seasons, as the year lasts only 365 days as compared with 687 days on Mars).

"But the climate (to which Earthmen would, of course, be adapted) with its stifling heat (for Earth is only two-thirds the distance of Mars from the sun and receives two and a half times more heat than Mars), humidity and enfeebling lack of temperature variation must be virtually unbearable. For example, night on Earth is only half as cold as day. How unlike our fine, envigorating temperature fluctuations at the equator; from + 5° C in the morning up to + 20° at noon, down to zero in the evening, and dropping to — 45° at midnight.

"There also appears to be no great temperature difference between Earth's Northern and Southern Hemispheres. This is because our neighbour's orbit carries it from a minimum of 147,000,000 to a maximum of 152,000,000 kilometres away from the sun, a difference of only 5,000,000 kilometres. This difference is almost 50,000,000 kilometres for Mars, which is why our Southern Hemisphere is so much warmer than the Northern. If Earthmen have telescopes they can observe that whereas our northern icecap never melts completely, the southern icecap occasionally disappears. The white spot around the terrestrial South Pole displays no such apparent change in size.

"We love our endless red-brown plains and our striking sandstorms and whirlwinds which an intelligent observer on Earth could see. Incidentally, it would be interesting to know what explanation they offered for the bright band which crossed the face of our planet on August 23, 1956?

"To eyes accustomed to the bluish-greenish-yellowish hues of Earth our colours might appear rather dark. Earthmen may even have given our planet some offensive, evil name.

"Our scientists have been studying the problem of life on Earth for many years. Large green spots have been observed in the neighbourhood of its equator. They may be manifestations of vegetable life, and on Earth plants probably reflect the green portion of the spectrum instead of absorbing it. But on high mountains and in cold regions terrestrial plants may make use of the 'green heat' and reflect blue light, like Martian plants.

"Unfortunately we still have no direct indication of the existence of animal or intelligent life on Earth. The bright flashes that are observed occasionally in the terrestrial atmosphere are, of course, a favourite topic of discussion among Martian scientists and science-fiction authors. They may be due to thunderstorms, which would naturally be fiercer than here as Earth is closer to the sun, but they may also be due to intelligent activity. Evidently the flashes that occur in our atmosphere must arouse the interest of our neighbours, if there are any.

"In short, if Earthmen exist they must have plenty of theories about the possibility and probability of life on Mars."

So much for the Martian point of view. What are the pros and cons for life on Mars from the terrestrial point of view?

PRO. Mars is an old and harsh world, and consequently evolution there has progressed further than on earth. Being smaller and more distant from the sun it cooled earlier. The planet's tempestuous volcanic youth of mountain formation was in the remote past. Its red colour is the colour of vast flat deserts.

The struggle for survival resulted in the evolution of highly developed forms of life, from blue plants to intelligent beings. Their civilization has outstripped the earth's, making especially great progress in the last hundred years or so.

Mars has two satellites, Deimos ("Horror") and Phobos ("Fear"), both discovered during the favourable opposition of 1877. Although Mars had been observed through comparatively powerful telescopes during previous oppositions, no one had ever seen them before. Since 1877 people have seen them through much weaker tubes. Could this mean that before 1877 Phobos and Deimos were simply not there to be seen? It has been suggested that they are actually artificial satellites.

Phobos circles Mars faster than Mars turns on its axis. A plausible explanation for this unique phenomenon is that it was initially launched to make one orbit in one Martian day, and for many centuries it hovered over one point of the equator. With time the equilibrium broke down and Phobos began to spiral slowly down to Mars, accelerating all the time. Scientists have calculated how long it would have taken Phobos to reach its present orbit; if the theory is true, then Phobos is not more than 400-450 million years old. This is a long time by human standards but very little on the cosmic scale. For if Mars is at least ten times older, why was it so tardy in acquiring a satellite for itself?

Thus, hundreds of millions of years ago, at the height of the Palaeozoic era on earth (this era of ancient life preceded the era of reptiles by as much as the era of reptiles preceded that of man), Mars was a different kind of world. It was not so cold and unchanging, and was possibly moist and warm. It was inhabited by a highly intelligent race capable of launching artificial satellites and building great canals. They may have visited the earth, as well as Venus and Jupiter. The earth proved too hot and stifling and its gravity was too great for comfort. Who knows but that traces of Martian visitors may lie hidden in Cambrian or Silurian deposits? Millions of centuries ago our remotest ancestors greeted them with fluttering gills, threshing tails and, at best, grunting and croaking. In 400 million years anything could happen to the most advanced civilization. After all, less than a million years separate us from the pithecanthropes!

Mars is old. Life is disappearing, if not already extinct. Archaeologists will have plenty to do there!

CON. A civilization sufficiently advanced to launch such satellites would have no difficulty in reaching the earth. Why haven't Martians called on us?

The satellites were not observed before 1877 because they are not easy objects for observation in the halo of light cast by their primary. Small celestial objects may be difficult to discover in a large telescope; but once discovered they can be seen more readily in a much weaker one. Astronomers and mathematicians hope to explain the peculiarities of Mars without resort to a hypothesis of intelligent beings.

PRO. Mars is covered with a network of cyclopic artificial structures (discovered from earth in that same year, 1877, and called "canals"). They are at least 48 kilometres across, which makes them too wide to be rivers or gullies. The canals represent an integrated network emanating from the polar caps. When the polar snows melt the precious moisture is caught and delivered to arid areas. From the earth one can see how the "canals" and "seas" into which they empty grow darker from time to time. Some canals branch out; at the intersections there are "great cities and industrial establishments" seen from earth as small dots.

CON. Mars is a senile world. It never harboured any "serious" organic life. At best it has mosses and lichens, otherwise its atmosphere would not have so little oxygen and so much carbon dioxide. Besides, there is hardly any water, not more than in one of the earth's great fresh-water lakes. The "canals" are natural fissures in the crust, and the darkening of the "seas" and "canals" is due to the play of light on lifeless rocks and sands.

PRO. The "canals" and "seas" absorb and reflect light, not like minerals, but like vegetation. There can be no doubt that the "canals" and "seas" are subject to seasonal changes of colour, while neighbouring desert areas are not. If the "canals" are simply fractures, why do they appear to form a unified system? When Martian conditions (temperature, pressure and atmospheric composition) were simulated in terrestrial laboratoires, higher plants, notably vegetables, far from perishing continued to thrive.

For all we know, Mars may be neither harsh nor old. Like the earth, most its surface is covered with oceans. They are, of course, icebound, and the ice is covered with eroded rock.

What we take for reddish desert is in fact ice powdered with dust. The polar caps are areas where the ice rises above the dust. The "canals" are cracks in the ice (possibly caused by meteorites) or areas of vegetation nurtured by the soil above the ice and the water beneath it. And water is the cradle of all life. In the course of evolution the higher forms of Martian life may have found refuge there.

It is as difficult to refute all these theories as to prove them. The time is ripe for a visit to Mars. The first step was made when the Soviet Union launched Mars-1, the first space probe to be sent up to the red planet. And even though the radio transmitter went dead when it was 106 million kilometres away, we should not forget that it was Mars-1. The exploration of Mars is continuing. The American probe Mariner-4 was able to take several "close-up" pictures of Mars, which will be very useful for future travellers to the planet.

COMPLEX RELATIONS

Relations between Mars and the earth are rather complex. Mars leisurely circles the sun once in two years in a long, elongated orbit. The earth moves much faster in an orbit which is nearly circular. The two planets come closest together approximately every two years. This is called their opposition, and the distance between them at this time is not more than 70 million kilometres.

Once in 15 or 17 years a "favourable opposition" occurs, when Mars is only 56-58 million kilometres away. The favourable oppositions of 1877, 1939 and 1956 yielded many important discoveries, although dust storms and bad weather on Mars in the autumn of 1956 greatly hampered observations.

The next favourable opposition is in 1971. It may even be celebrated with a fireworks display over the Martian canals!

A GIANT IN ORBIT

Obviously the name of the chief god could not be given to just any planet, and Jupiter's mass is more than double the combined mass of all the other bodies revolving round the sun. The giant globe circles the sun at an average distance of 800,000,000 kilometres moving with majestic equanimity. It is followed by a retinue of 12 satellites, and completes one circuit in 12 years. It would take 318 earths to make one Jupiter, and 1,047 Jupiters to make the sun.

One of the great unsolved mysteries of the solar system is why there are four small planets, Mercury, Venus, Earth and Mars, and then the giants Jupiter, Saturn, Uranus and Neptune.

A rocket travelling with a "conventional" speed of today would take several years to reach the neighbourhood of Jupiter. As it approached the planet it would pass into dense clouds of hydrogen, methane and ammonia barely warmed by the sun's rays to a temperature of

—100° C. Several thousands of kilometres inside the Jovian atmosphere the rocket would reach a strange kind of medium, becoming denser and hotter due to the rising pressure. It is hydrogen, but of the density of water, and the rocket would no longer be flying but sinking into a vast ocean of hydrogen tens of thousands of kilometres deep. As a matter of fact, it would be hard to draw a line between Jupiter's atmosphere and its surface, and scientists define the body of the planet as the whole of its opaque part.

Jupiter revolves on its axis three times faster than the earth, different parts of the globe rotating with different speeds like a liquid body (incidentally, at some depth the pressure and temperature must be the same as in terrestrial oceans).

Finally the rocket would reach the floor of the hydrogen ocean. Beneath it lies a core, solid and very dense, subject to pressures of tens of millions of atmospheres and temperatures of tens or even hundreds of thousands of degrees. This is a world so unlike the one we know that it would be ill-advised to declare outright that no forms of life are possible there.

Two strange features have been puzzling astronomers for a long time. One is a huge red spot, 10,000 kilometres wide and 50,000 kilometres long, equal in area to the earth. It is presumably solid, though light enough to float at a considerable altitude above the planet's core. It has been observed for more than 80 years. Clouds do not pass over the Red Spot, as though they were being dispersed by some unknown force. At one time some scholars thought it was a lake of incandescent lava. The spot occasionally dims, as if it were sinking into the hydrogen deeps.

The other object of a long-enduring nature has been observed since 1901 as a dark band some 70,000 kilometres long. Known as the South Tropical Disturbance, it contains a bright spot which is a powerful source of radio waves.

Jupiter offers much food for thought and speculation, but its secrets are still well guarded.

A RINGED WORLD

The planet that bears the name of the god Saturn would not sink even in a bath of kerosene. It is a globe of hydrogen, ammonia and methane 760 times the earth in size but with a density only 0.133 that of the earth.

At a distance of 1,500,000,000 kilometres from the sun, Saturn receives not more than one per cent of the solar warmth we on earth enjoy. We might say that the temperature on Saturn is at least 150° C below freezing point but, like its giant neighbour, Jupiter, the observable surface of Saturn is but the top of an opaque atmospheric ocean. We know nothing of what lies hidden beneath the vast belts hovering over the planet's tropical zones, the occasional bright spots and the rapidly rotating transparent layers (Saturn makes one revolution on its axis in just over ten hours). Deep down, temperatures of thousands of degrees and pressures of thousands of atmospheres probably prevail.

Circling this mysterious gaseous globe are nine satellites and three huge concentric rings hanging over its equator like an eternal rainbow. We can only conjecture as to the origin of Saturn's spectacular system of rings which are almost a million kilometres long, yet probably not more than 10-12 kilometres thick. They are made up of myriads of particles ranging from a few microns to several metres in size and they serve as a warning to future visitors: he who departs at a speed of less than 37 kilometres per second will not escape.

NAMED AFTER GRANDFATHER

No one was ever born under the sign of Uranus for the simple reason that it was unknown when astrologers first began to interpret the signs of the zodiac in relationship to the planets.

Then, on March 13, 1781, the English astronomer William Herschel discovered a new planet with his seven-foot reflector. The immediate results of this great discovery were that Herschel was awarded the position of Astronomer Royal with an annual salary of 200 pounds sterling, and an attempt was made to name the new planet Georgium Sidus after King George III. However, the ancient gods took precedence over the English monarch. As Saturn is the father of Jupiter, it was natural to call the next planet after Jupiter's grandfather, Uranus.

From a distance of almost 3,000,000,000 kilometres the sun appears as a bright star shedding 370 times less warmth than on earth. Very slowly, in 21 terrestrial years, it rises in the sky of Uranus. The setting of the sun takes another 21 years before it disappears behind the horizon and a 42-year night begins. To be sure, the huge globe of Uranus (its diameter is 3.8 times greater than that of the earth) turns rapidly on its axis, making one revolution in 10 hours 42 minutes. But it is the only planet whose axis is not just inclined, but lies almost in the plane of its orbit. (This is the reason for the great length of the planet's days and nights.)

Five satellites, called Miranda, Ariel, Umbriel, Titania and Oberon, attend the seventh planet, which is enveloped in a thick, green, incredibly cold (— 200° C) atmosphere of methane and hydrogen. Although Uranus is the third planet in size no clear surface details have been observed. Its average density is slightly greater than that of water, which indicates that it is probably similar in composition to Jupiter and Saturn. The escape velocity from Uranus is 21.2 km/sec, twice that from the earth.

AT PENPOINT

It is claimed that Leverrier never even deigned to have a look at the planet which he (and independently J. C. Adams) discovered "at the point of a pen". It was all very simple. On September 23, 1846, the Berlin astronomer Galle received a communication from Leverrier specifying the point in the sky where the new planet should be sought. That evening Galle peered into his telescope, and there was Neptune.

More than a century has passed since then, but one Neptunian year will be completed only in the year 2011 (as it equals 165 terrestrial years). The eighth planet in the order of distance is 4,500,000,000 kilometres from the sun, and it receives 900 times less warmth than the earth. Its closest neighbour, Uranus, is 1,500,000,000 kilometres away which, however, does not prevent these two stark worlds from being very similar. Neptune is slightly smaller than Uranus (3.6 the earth's diameter), but denser. It contains more than 17 terrestrial masses, its escape velocity is 23.5 kilometres per second. It possesses the same kind of greenish methane atmosphere as Uranus, only it is colder (below — 200° C).

Neptune has two satellites. There appear to be two bright surface features, but nothing is known for sure.

THE LAST?

The name of the god of death would hardly have been given to a pleasant world. Assuming every planetary month to be 1/12th of its year, then little more than one and a half months have passed on Pluto since the American astronomer C. W. Tombaugh discovered it on February 18, 1930. Since then astronomers have determined its distance from the sun, which is 39.5 astronomical units (an astronomical unit is the mean distance of the earth from the sun), that is to say, almost 6,000,000,000 kilometres. A beam of light from the sun takes five and a half hours to reach Pluto, and although the sun is considerably brighter there than the moon on earth, it is unable to warm the ninth planet to more than —220° C. This temperature is low enough for practically all gases to be in the liquid, or even the solid, state, and for that reason Pluto probably has no atmosphere to speak of.

Coming as it does after the four giants, Jupiter, Saturn, Uranus and Neptune, Pluto appears as a rather insignificant globe, probably smaller than the earth. It has even been suggested that it might actually be a remote satellite of Neptune, especially as it travels in an unusual orbit which brings it, at its perihelion, closer to the sun than Neptune.

Another recent hypothesis is that there exists a tenth, trans-Plutonian, planet. It would be much bigger than Pluto, lying at a distance of 77 astronomical units (11,500,000,000 km) from the sun, with a year equal to 675 terrestrial years. If this theory proves wrong, then we can regard Pluto as lying on the shore of an empty cosmic ocean whose opposite coast (the closest star) is 7,000 times farther away from the sun than Pluto. A space ship travelling at 20 km/sec would take ten years to reach Pluto and another 70,000 years to reach the nearest star, Proxima Centauri.

GRANDCHILDREN OF THE SUN

When Christian Huygens, the celebrated Dutch mathematician, physicist and astronomer, discovered in 1655 that Saturn had a satellite, he declared that at last a harmonic number of luminaries had been found (the sun, five planets and six planetary satellites). This "harmony" has long since been violated, and as of today the solar system comprises nine major planets, 31 satellites (not counting the manmade ones, of course), thousands of minor planets called asteroids, comets, meteoroids and other interplanetary debris.

One might say that the planets are the "children" of the sun, and their satellites its "grandchildren". Not many years have passed since the twelfth satellite of Jupiter, the second of Neptune and the fifth of Uranus were discovered, and the number of "grandchildren" may yet increase.

Mercury, Venus and Pluto have no moons of their own, Mars has two tiny moonlets, Jupiter has 12 attendants, Saturn 9, Uranus 5, and Neptune 2. One will readily observe that as far as the number of satellites is concerned the earth, with its lone moon, occupies a modest sixth place. On the other hand the moon is a good-sized satellite, inferior only to Jupiter's Ganymede and Callisto (which, incidentally, are even bigger than the planet Mercury), Neptune's Triton, and Saturn's Titan.

In other respects, however, the moon is a champion among satellites. Firstly, it is the brightest. The huge satellites of the remoter planets are dim disks in their skies. Secondly, the moon is only 81 times smaller than its primary; in comparison, Triton is 1/770th of Neptune, and Titan is 1/4,000th of Saturn. Astronomers as yet have no explanation for the comparatively great size of the earth's "child". Nineteen satellites are more distant from their primaries than our moon. One member of the Jovian dozen lies as far as 25,100,000 kilometres from its primary, completing one revolution around it in 745 days.

Each of the sun's "grandchildren" is a world in its own right, with features in common with others and unique to itself. Some time in the future they will undoubtedly serve as observation bases, interplanetary rocket launching sites and scientific stations. Here are some interesting features of some of the satellites.

Appreciable atmospheres of ammonia and methane have been detected on Triton and Titan.

Maps of Jupiter's four biggest satellites have been drawn. Like our moon, their periods of rotation around their axes equal their periods of rotation around their primary, so that the same side is always facing it.

The satellites of Uranus and Neptune move around their primaries counterclockwise (retrograde motion); all the other satellites move in a clockwise direction.

The most mysterious celestial objects are the satellites of Mars. They are the only ones that revolve in the equatorial plane of their primary (the plane most convenient for the launching of artificial satellites!). They move in low orbits; Phobos at an altitude of 9,400 km (this is the distance from Moscow to the Pacific Ocean), and Deimos 23,500 km away. Phobos is 16 km, and Deimos 8 km in diameter. They are fast-moving objects, and Phobos is the only satellite which circles its primary faster than the primary turns on its axis (Mars makes one turn in 24 hours 37 minutes, and the period of Phobos is 7 hours 39 minutes, so that it rises and sets twice in the course of a Martian day). Owing to their small size the Martian satellites are very difficult objects for observation, and some of the data concerning them must be verified. If certain peculiar features in the motion of Phobos are confirmed the only plausible explanation will be that the satellite is hollow inside, something quite unthinkable in the case of a natural cosmic body. An artificial satellite would, of course, be hollow. The Soviet astronomer Iosif Shklovsky, who has advanced a hypothesis according to which the Martian satellites might be artificial, once remarked that astronomers often deal with much more improbable theories, regarding his own as "rather ordinary ... neither better nor worse than any other".

Diameters of eight and sixteen kilometres are very small for natural satellites but huge for artificial ones. On the other hand, many remarkable features of these little globes are easily explained on the assumption that they were launched by intelligent beings.

Incidentally, it will be observed that in general the bigger a planet the more satellites it has. Jupiter has the greatest number while Venus, which is slightly smaller than the earth, has none. But Mars is smaller than Venus, and according to this rule ought to have no satellites. This, of course, is merely a consideration and not a proof, but who knows....

NO INTRINSIC LUMINOSITY

Legend has it that at the court of the Emperor of China there once lived two astronomers. Hi and Ho. They were thirsty souls who studied tankards of wine much more often than the skies. One morning an eclipse of the sun began. The inhabitants of the capital were seized by panic; quite obviously a huge dragon was devouring the sun. Happily the sun was rescued from the dragon's mouth, but the Emperor ordered the two unfortunate astronomers to be beheaded for their oversight.

Today we know the true nature of the evil dragon that cost poor Hi and Ho their lives, and people no longer panic when the moon eclipses the sun. In some respects we know more about our celestial neighbour than about our domestic affairs. The tomes of monographs and theses devoted to the earth's attendant could pave all the 384,000 kilometres separating us from the moon. But it took a long time and a great deal of work to write them.

At first it was hard for people to accept the idea that the moon possesses no intrinsic light but, like the earth, shines with the reflected light of the sun. It was easier to understand that the moon travels around the earth in a long circular orbit. Men calculated the time it takes to complete one orbit—27.32 days—and called it the sidereal month. They measured the time (29.53 days) it takes the moon to pass through all its phases—new moon, first quarter, full moon, last quarter—and called it the synodic month.

The moon is, of course, a favourite topic for poets and science-fiction writers. Astronomers offer more "prosy" descriptions of it: mass 72,000,000,000 tons, equatorial diameter 3,482.8 km, volume 0.02 that of the earth, temperature of the sunlit side 110° C, visible motion across the starlit sky one diameter per hour from west to east (not to be confused with its apparent diurnal motion from east to west, due to the earth's rotation).

Of late the science-fiction authors' interest in the moon has waned considerably, and they have forsaken it for Mars, Venus and other planets. Scientists, however, continue to study it with unabated interest. On September 14, 1959, they presented the moon with a gift from the earth; a pennant with a star, hammer and sickle embossed on it delivered by Luna-2.

What awaits the first men on the moon? Some say they will sink into ten or more metres of dust. Others think that the astronauts will find a solid, pockmarked surface with steep-walled, sharp-edged hollows, littered here and there with volcanic debris. The most plausible hypothesis is that the lunar surface consists of a spongy material like pumice or slag. We shall discover the truth when an automatic probe carries out on-the-spot tests, including drilling, seismic studies and other investigations. This research will also provide clues as to the origin of the moon.

At the end of the 19th century George H. Darwin advanced a theory of the origin of the moon according to which the moon was once part of the earth and broke away in some manner. However, it now appears that the earth and moon differ substantially. The flight of the Soviet Lunik, for example, showed that the moon lacks a magnetic field like the earth's.

Adherents of the "meteorite" theory, developing the ideas of Otto Schmidt, consider that the moon is an asteroid captured by the earth, with swarms of meteoric material adhering to it. Harold Urey thinks that the moon was once a fully-fledged planet of the solar system but at some stage was captured by the earth. The Bulgarian astronomer N. Bonev declares that, due to enormous volcanic eruptions, the moon lost part of its mass, altered its course and became a satellite of the earth.

The characteristic lunar landscape of vast craters can be observed with a pair of field glasses. Were these craters created by volcanic activity or meteoric impacts? The origin of the moon is one of the exciting mysteries of cosmogony.

On October 29, 1963, two astronomers of Lowell Observatory in the United States could hardly believe their eyes when they suddenly saw a bright red light in the crater of Aristarchus. At first they even suspected that something was wrong with their telescope (aperture

60 cm). When, 28 days later, the edge of the moon's disk reappeared there were four men ready waiting at the telescope eyepieces. For 45 minutes they observed a brilliant ruby-red sparkling strip 2.5 kilometres wide and 20 kilometres long. Its nature is still a mystery.

Today the exploration of the reverse side of our satellite is even more exciting. As the moon's period of rotation on its axis is exactly the same as its period of rotation round the earth, it always presents the same face to us. The moon evidently did once possess axial rotation relative to the earth, but it was retarded by tidal friction until it was brought to a "standstill". The other side of the moon has always been hidden from earthmen. One can understand the flurry of excitement with which people greeted the pictures of the far side taken by the Soviet automatic interplanetary station in October 1959. New names appeared on the map of the moon; Sea of Moscow, Tsiolkovsky Crater, Giordano Bruno Crater, Kurchatov Crater, etc. Five years later the American space probe Ranger-7 took more than 4,000 pictures of the moon's surface in the last 17 minutes before crashing into it. These photographs seem to indicate that the surface of the moon is generally hard and resembles a layer of solidified lava beneath an inch-thick layer of dust. The pictures still do not uncover many secrets, even though subsequent Ranger launchings yielded several more series of photographs.

But the moon harbours not only mysteries.

Power engineers say: the power of the tides caused by the moon is untapped treasure.

Geophysicists: tidal motion in the solid body of the earth is more interesting. Study of this may give a clue to the internal structure of the globe.

Radio engineers: the earth's natural satellite can be used to set up a world-wide television network.

Astronauts: the moon is an excellent launching pad for space vehicles. The force of gravity is six times less than on earth, and the escape velocity is accordingly only 2.4 km/sec, one-fifth that of the earth. Besides, the moon has no air-induced drag. In the future it will serve as an intermediate station for rocket routes from the earth into the universe.

Astronomers: on the moon one only needs to "shut out" the sun to produce an eclipse and observe the corona. The stars don't twinkle but shine evenly in the black sky. There is no air to distort telescopic images, and it is possible to build giant refractors with tremendous resolving power. Last but not least, the terrestrial atmosphere is transparent to very few radiation wavelengths and it absorbs almost completely the extreme short-wave end of the spectrum beyond the ultraviolet: cosmic rays, gamma rays, X-rays and solar corpuscular radiation. On earth this part of the spectrum can be studied only by various indirect and rather unreliable means. On the airless moon there will be no need to build observatories high up in the mountains.

On the other hand, before landing on the moon, people will have to learn to protect themselves from the hazards of radiation.

There can be no doubt that the time is not far off when explorers will look down into the lunar craters. It will not be long before the bright sickle of the moon ceases to be a question mark in the starlit sky.

THE USE OF ALBEDO

Albedo sounds like the name of a Spanish city. Actually, it means "whiteness" and it designates the fraction of the total incident light which is reflected back in all directions by any surface.

One usually has no difficulty in distinguishing a piece of wood from a piece of metal, glass from stone, or aluminium from copper. The material from which an object is made can be determined from such properties as colour, brilliance and transparency. What is the moon made of?

Viewed through a telescope, the moon appears to be extremely bright. Once astronomers even thought that lunar continents were covered with snow and lunar seas with ice. The impression, of course, is a false one, due to the fact that a large, brightly illuminated surface is being viewed against a dark background.

When men start landing on the moon they will want to know the type of terrain they will have to negotiate. Will a cross-country vehicle do? What will they find there: bare rock, sands, thick layers of dust and volcanic debris? What awaits us on other planets?

Albedoes observed astronomically and compared with those of known substances measured in the laboratory can give valuable clues as to the nature of the surface of a celestial body.

The moon's albedo was found to be 0.073, i.e., it reflects only 7.3 per cent of the incident sunlight. In other words, the face of the moon is not so brilliant as it seems. It is darker than dry fertile black soils or basalt. Furthermore, rays of different colours are reflected from the moon with different intensity. The albedo is highest for red light, which is why the surface takes on a dark reddish hue. When the first lunar stone is brought to earth it will be a dark brownish-grey.

The albedoes of the planets are higher than that of the moon, but we are unable to see the solid (or liquid) surface of Venus, Jupiter or Saturn because of the density of their atmospheres. On the other hand, investigation of the albedoes of planets with transparent atmospheres, like Mars or Mercury, is a useful preliminary to the development of Martian or Mercurian mineralogy.

TAIL FORWARD

They were once the most feared and cursed of all celestial bodies. They were thought to be heralds of evil tidings. "Woe upon me," Louis the Pious is reputed to have said, "I know that the appearance of a comet heralds a change in the reigning monarch in my country." A historian wrote of the comet of 1527: "It aroused such great horror that many people died of fright and many took ill." Unable to comprehend the meaning of events, people shook their fists in anger at the skies, regarding the tailed stars as the cause of many evils.

However, it all depends on one's point of view. When Pope Calixtus III saw the comet of 1456 he proclaimed that it had the shape of a cross and interpreted it as a blessing on the Crusaders. Let the heathen Turks beware! But the Turks found that the comet's curved tail was more like a yataghan. The Pope withdrew his interpretation, cursing his own blindness and the comet.

As astronomy advanced comets lost their mystery. "There are as many comets in the sky as fishes in the ocean," Kepler said. Today some 900 comets have been registered and the orbits of 548 have been calculated. Superstitious prophecies were replaced by scientific predictions, and when the comet of 1758 appeared it was expected, having been predicted by Halley. Every 76 years it comes back to the sun, an old guest whose visits have been traced back to the year 240 B. C.

Their orbits round the sun sometimes take comets away for thousands and even millions of years. But there are many short-period comets, which reappear every 3-10 years. Their faithfulness, however, costs them dear. They lose their brilliance and soon turn into obscure nebulous patches of light. Half of the 64 such comets have already thus disappeared from sight. What is the reason for this? The nucleus, the only solid part, is probably made up of frozen methane, ammonia and carbon dioxide with stone particles embedded in it. As the comet approaches the sun it begins to put on its spectacular attire. The frozen gases sublimate, a gaseous envelope, the coma, appears, and a tail streams out. The coma and tail are made up of particles of gas and dust ejected by the nucleus.

But the gorgeous attire is the robe of death. The more frequent a comet's return to the sun the faster is the material of the nucleus dissipated into the coma and tail. In several decades such a comet dies of exhaustion. It fails to reappear on the scheduled date and is entered into the list of lost comets.

Sometimes a comet provides a farewell performance before disappearing forever. In 1846 Biela's comet split into two parts. The two comets travelled side by side and when they returned in 1852 they were seen to be rather more widely separated and much dimmer. They approached the sun and disappeared. They were not seen in 1859 or 1865, but on November 27, 1872, there occurred a spectacular meteor shower which came from a point that was shown to have a position in agreement with the elements of the comet's orbit.

The cause of a comet's death is apparent. But what of its birth? Opinions vary. It has been shown that comets are the offsprings of the solar system. According to one theory they came from a planet that disintegrated thousands of millions of years ago somewhere between Mars and Jupiter. According to another theory they are produced by matter erupting into space from planets.

Comet tails may extend for millions of kilometres. The tail of the 1811 comet was longer than the distance from the earth to the sun. As for their density, imagine a grain of wheat crushed to powder and dispersed in a big theatre. In fact, comets have been called "visible nothingness". The coma and tail are made up of super-rarefied gas. Under the sun's action the nucleus ejects particles into the coma, and then a repulsive force retards their motion and hurls them back. This force, discovered by the Russian physicist Pyotr Lebedev, is the pressure of light. That is why all cometary tails are directed away from the sun, even when the comet is receding.

Cometary tails sometimes behave rather erratically. When Comet Burnham 1959 approached the sun it actually began to wave its tail, the amplitude reaching 15 degrees and the period being almost 4 days. The phenomenon was observed during the whole time the comet was in sight, and when it disappeared it took its secret away with it.

In short, people's superstitions about comets are completely unfounded. They follow their paths in space without doing harm to a soul. Even when they do graze a planet this has no ill effects whatsoever, just as the earth's encounters with comets in 1801 and 1910 passed completely unobserved. Incidentally, the chance of a collision with a comet head is one in 80 million years, and one will hardly take place in our time.

TOWARDS THEIR DEATH

No one knows where they come from. They just come, have a glimpse of the earth, and perish. Their death is the most spectacular event in their life. For millions of years these dark, inconspicuous little objects wander about in space. Most of them are not bigger than a pinhead, though some are more substantial. They are made of stone or iron mixed with nickel. They enter the atmosphere at a tremendous speed, produce a fiery streak at a height of anywhere from 130 to 80 km, vaporize, and go out, usually some 40-60 km from the ground. What one observes is the trail of a ball of incandescent gas creating a halo around the falling particle. (The word "meteor", incidentally, is derived from the Greek word meaning "phenomenon in the sky".)

For ages people believed that each man had his own star, without suspecting that they could see not more than 3,000 stars in the sky with the unaided eye. A "falling star" meant that someone had died. On an ordinary night one can observe a dozen shooting stars. But what about meteor showers in which they fall in thousands?

One might begin to think that the end of the world had come. That may have been why an 11th-century Japanese emperor proclaimed an amnesty when an especially abundant meteor shower took place. Today people are not so superstitious; 20,000 meteors in one hour on October 9, 1933, failed to open the door of a single prison cell.

Not many meteors reach the ground without disintegrating. Only the biggest and brightest (some of them up to a million candlepower), known as fireballs and bolides, do so.

The bodies that reach the ground become known as meteorites. By 1938, only 1,210 had been found, although hundreds of tons of meteoric matter falls on the earth daily. (One of the results of this is that the earth gains in weight and its rotation on its axis slows down imperceptibly.) By the time a meteorite reaches the ground it has usually lost most of its cosmic speed and creates little damage. However, the impact of giant meteorites weighing many tons (the biggest one, Hoba, weighs 60 tons) leaves appreciable scars. Meteor Crater in Arizona, U.S.A., is a vast pit 4,000 feet in diameter produced by the fall of a meteorites some 50,000 years ago.

The origin of meteorites is debatable. Those which follow elliptical orbits are associated with comets; those following hyperbolic orbits are associated with galactic nebulae. Once again we must concede that the heavens guard their secrets jealously. Meanwhile we can repeat the words inscribed on a meteorite which fell on November 7, 1492, and which the inhabitants of a small German town chained to a wall in the local church as if to keep it from returning to the sky:

"Many people know much about this stone, and some know something, but no one knows everything."

MIDGET PLANETS

There was once a planet between Mars and Jupiter. Mars pulled it weakly, while Jupiter pulled more strongly. The planet disintegrated. This is one version.

It harboured a civilization which reached a stage where nuclear explosions ripped the planet asunder. This is another version.

There are other theories explaining the origin of the thousands of tiny planets circling the sun between Mars and Jupiter in what is known as the asteroid ring. One of them may prove correct.

Ceres, the biggest asteroid, with a diameter of 770 km and an area approximately equal to Mexico, was discovered on New Year's Eve, 1801. Today there are some 1,700 registered minor planets, and the total number in the solar system is estimated to be as high as 100,000. Taken together, however, their total mass is not greater than 1/1,000th that of the earth. Ceres, Pallas, Vesta and Juno are giants, as asteroids go, with diameters of several hundred kilometres. Other asteroids are much smaller.

Asteroids display a variety of features, some of them very strange and remarkable. None of them, of course, has an atmosphere. Gravitation is negligible. Shapes vary. Eros, for example, is a cigar-like body 35 km long and 7 by 16 km in cross section. Others are like rock fragments scattered by a stupendous explosion. Among the hundreds of colourless little planetoids one suddenly observes bluish Fortuna or reddish Amherstia. Several have been ejected by some unknown force from the ring between Mars and Jupiter: Hidalgo flies out as far as Saturn, Hermes (about the size of New York's Central Park), on October 28, 1937, passed the earth at a distance of only 780,000 km, and then got lost, and Icarus (which could accommodate a small town) is probably the only member of the solar system which has occasion to glow with intrinsic light—at perihelion it comes twice as close to the sun as Mercury (28 million km) and the waves of the turbulent, fiery solar ocean lap its shores. Unlike the mythical Icarus the asteroid does not fall but obeys the great laws of gravitation and sails off to cooler regions.

In some respects asteroids are rather a nuisance. They are difficult telescope objects, hard to discover and easily lost. Naming them is another problem as the supply of goddesses, after whom the first asteroids were named, soon ran out. Today they are given more down to earth names, like Vladilena (after Vladimir Lenin), Pavlovia, Amundsenia, Lomonosova. One asteroid has been named Moskva (for Moscow). Nevertheless, there are more minor planets than suitable names.

However, these midgets of the planet world have helped to make some important contributions to science. Notably, they have helped astronomers to check data relating to the sun and major planets.

On January 2, 1959, the first manmade member joined the big family of asteroids. This is the Soviet space rocket Luna-1, which revolves round the sun with a period of 450 days.

THE RECORD OF AC +70°8247

The lecturer held up a piece of chalk to represent "the planet Earth". The blackboard one metre away became the sun.

"On this scale," he said, "one metre equals 150 million kilometres. How far away would the closest star be?"

The audience ventured guesses. One man suggested that it would be somewhere in a neighbouring street. Bolder listeners thought the city outskirts would be more correct. They, too, were wrong, for the star would have to be placed 300 kilometres away.

The first flights into outer space have brought us several hundreds of kilometres nearer to the stars. These are the initial steps. One day man will reach Mars, and will have penetrated several tens of millions of kilometres into the cosmos. But the fastest conceivable traveller in the universe, a ray of light, takes more than four years to reach the nearest star. A man who has reached Mars and plans to travel to Proxima Centauri is like a child who, having made his first steps from the cradle, wants to hike from one city to another. Light from the brightest star, Sirius, takes nine years to reach us; rays from Capella in the constellation Auriga have been en route since the early 1920s; Antares "takes us back" to the times of Peter the Great, and Deneb, to the Crusades—270 and 800 years travelling at 300,000 km/sec!

The distant worlds of the stars are inaccessible to man, yet we know a great deal about them. Modern telescopes can reach out to regions of space as far as 13,000 million light years away. Over this tremendous distance there lie scattered huge amalgamations of billions of stars—galaxies of different kinds.

How many stars are there in the sky? The answer to this ancient question is that the unaided eye can see about 3,000, and the biggest telescopes thousands of millions (all the known galaxies contain some 10^{20} stars). The luminosity of stars is stated in terms of stellar magnitude. A star of magnitude 1 is 100 times brighter than a star of magnitude 6. The higher the stellar magnitude the weaker the star. At present all stars brighter than magnitude 11 have been counted and recorded in catalogues. There are about one million of them, plus another 2,000 million weaker stars. Modern telescopes are capable of discerning stars of up to the 23rd magnitude.

Stars and constellations had to be named, and the ancients imagined the heavens populated with familiar animals such as the lion (Leo), the whale (Cetus), the giraffe (Camelopardalis), the swan (Cygnus), the eagle (Aquila), and the bear (Ursa), and also with fantastic creatures, like the unicorn (Monoceros), the sea serpent (Hydra) and the dragon (Draco). The southern hemisphere of the sky, studied only in the last hundred years or so, has been furnished with more modern and useful things: the microscope (Microscopium), the telescope (Telescopium), the compass (Pyxis), and even the chemical furnace (Fornax Chemica).

The constellations do not change their shape, and we see them today just as the pharaohs of

Egypt saw them. Does this mean that the stars are motionless? Not at all. They move about in various directions with different speeds. The fastest known star is in the constellation Columba (The Dove), and it is travelling at a speed of 583 km/sec, twice as fast as the sun.

The motions of stars can be observed only by using very precise instruments, as the distances are so great that angular displacements are negligible.

Our sun is a very ordinary star. But here are some of the champions of the Milky Way galaxy. The star Epsilon B of the constellation Auriga (The Charioteer) holds three records: it is the biggest known star (2,700 times bigger than the sun in diameter so that in the sun's place it would extend beyond the orbit of Saturn); the most tenuous (only 25 times heavier than the sun, its density is an infinitesimal fraction of that of the terrestrial atmosphere); and the coolest (the temperature of its outer regions is only 1,300°C).

The smallest star, Number 45 in Wolf's catalogue, is about the size of the moon, but its mass is equal to that of the sun. Its matter is compressed to an enormous degree. But the densest star is AC +70°8247, as it is denoted in astronomical catalogues. A piece of matter from it the size of a pinhead would weigh 36 kg on earth.

The brightest star is Zeta Scorpii. In the sky this distant star is of magnitude 3, but if it occupied the place of the sun it would be hundreds of thousands of times brighter.

The dimmest star is Lalande 212558 B, and if it replaced the sun it would appear to us dimmer than the moon.

The hottest stars have surface temperatures of 50,000 to 100,000°C, but the temperature champion is not known for sure.

What is a star? What celestial body can be classified as a star? The basic characteristic is mass. A body with a mass smaller than 1/100th of the sun's cannot shine with intrinsic light. It takes a large mass to produce the internal temperatures and pressures which can sustain the nuclear reactions and energy emission required to make a body luminous. Until recently the biggest stars were thought to contain some 100 solar masses. But in 1963 super-giants were discovered; one such star could make millions of suns.

Many stars, known as binaries, come in pairs revolving about a common centre of gravity. Epsilon B Aurigae has a companion, Epsilon A, which is 3,000 times smaller in volume. They are like a watermelon and a seed. There are also multiple families of three and more stars. If the distances between such multiple stars are comparable with their radii, gravitational forces tend to draw them out and elongate them like eggs. The members of a binary system in Ursa Major (The Great Bear) are so close to one another and so elongated that their shells actually touch.

Many stars vary in brightness. Some fluctuate at random, while others show great regularity. A typical periodic variable is Delta Cephei, which varies in brightness by 0.75 stellar magnitude in a period of 5 days 10 hours 48 minutes. A whole class of variable stars has been named the *Cepheids* after it. These are so-called pulsating variables in which the change in brilliance is due to physical causes resulting from processes taking place within the star.

Another class is made up of the so-called eclipsing variables. These are binaries, and the change in luminosity is caused by regular eclipses of one star by the other as they revolve around their common centre of gravity.

Time and again vast explosions occur in different parts of the universe. Dim little lights suddenly flare up into "new stars", or novae, as they are called. Chinese, Arab and other chronicles over the last two thousand years mention several remarkable outbursts of new stars. Some were so bright that they could be seen in the daytime. Such stars are called supernovae, or "super-new" stars. Every "quiescent" star derives its supplies of energy from thermonuclear reaction. Then, for some unknown reason, the normal course of the reaction is disturbed, and the star explodes and ejects glowing clouds of gas that are observed as a nebula surrounding it. According to one theory, novae develop in a peculiar interaction between binaries in which a giant and a dwarf exchange matter and "turn into one another" ("dog eats dog", as the American astronomer Fred Hoyle describes the process). A nova explosion may be a recurrent process but a star can become a supernova only once. It has been suggested that the earth has been subjected several times to extensive cosmic ray bombardment from relatively close novae and supernovae.

Many stars probably have planetary systems of their own, and some planets may harbour intelligent life. It has been suggested that at least three stars less than 17 light years away from the earth have planets, and attempts have even been made to receive signals from them in the hope of getting into contact with their inhabitants. Of course, the conversation would take more than 30 years, even if it consisted only of a single question and answer. Such are the distances between stars with which man must reckon.

SMOKY SPACE

Space is rather dusty. The surface of the moon is covered with dust. Meteors entering the earth's atmosphere disintegrate into dust. In its eternal peregrinations through space the earth captures specks and particles of dust which stretch out behind it in a long train. When the time comes to place telescopes in orbit to study the remotest stars it will be necessary to lift them not less than 2,000 kilometres above the surface as the dust there is not so thick, though it does not disappear completely. The outer part of the sun's corona, which can be seen during an eclipse, is due to cosmic dust. The faintly luminous band extending along the whole length of the ecliptic, known as Zodiacal Light, is due to the reflection of sunlight from vast clouds of dust.

Maps of the skies denote dark nebulae like ordinary geographical maps denote swamps. They are drawn out like cirrus or cumulus clouds or condensed into spheres or globules. Interstellar dust makes the light of many stars appear reddish, as it absorbs blue rays.

When astronauts leave the confines of the solar system to travel from star to star they will find that the density of cosmic dust is negligible indeed, with some of the darker dust nebulae containing not more than one speck in several cubic kilometres. And as the average speck of dust in an interstellar cloud is not more than 1/1,000th of a millimetre in diameter, some scientists speak of interstellar smoke to distinguish it from larger-sized meteoric dust.

As they say, there is no smoke without fire, and cosmic smoke is produced in the fires of stellar furnaces. The eternal turbulent motion of clouds of smoke, dust and gas sometimes forms denser condensations and globules in which one of the greatest mysteries of Nature, the birth of new stars, takes place. Science has yet to give an explanation for Nature's great cycle of matter in which tiny specks of dust with temperatures close to absolute zero give birth to natural thermonuclear reactors within stars or to cold planets on which intelligent life may appear millions of centuries later.

WHAT'S IN A POINT?

When an artificial satellite travels around the earth it is subject to the gravitational attraction of both the earth and the moon. When the orbit is low the moon's attraction is negligible and need not be taken into account. At considerable distances, however, the pull of the moon may be sufficient to change the satellite's orbit beyond recognition. In certain conditions some interesting results may occur.

For instance, a terrestrial observer may suddenly find that the artificial satellite has come to a halt in space. Moreover, the same would be true for an observer on the moon. In the earth-moon system there exist five remarkable points, called libration points. Under suitable conditions a body entering them stays there. Three of them, lying on the straight line joining the earth and the moon, are points of unstable equilibrium, like the crest of a hill. A body that leaves such a point will continue to "roll" away. The two other points each lie at the apexes of equilateral triangles with the centres of the earth and moon at the other apexes. They are gravitational "pits", and a body near one of them will oscillate around it as if held by an invisible spring. The sun-Jupiter system also has such points, and astronomers long ago discovered five small asteroids oscillating around one of the system's stable points and eight around the other. Attempts were made to discover bodies in the neighbourhood of the libration points of the earth-moon system, and finally the Polish astronomer K. Kordylewski was able to photograph two faintly luminescent spots near one of them. They are actually clouds of tiny particles. Although about the size of the earth, their mass is negligible, and

Kordylewski estimates that they contain not more than one particle per cubic kilometre of space.

Several hypotheses have been suggested as to the origin of these satellite clouds. According to one, they are the residue of dust ejected from the moon's surface by meteoritic impacts. The clouds thrown up into space collect at the libration points much as snow collects in pits and gullies in a blizzard. Some of the particles swing past the libration points and are swept on into space. The number of meteorites falling on the moon varies considerably and on some days, when it passes through a meteor stream, meteor showers rain down on it. If this theory is correct, the spots at the libration points should become brighter at such periods because of the increase in density due to particles swept in and out of the "pit". If periodic increases in the luminosity of the clouds are observed this will confirm the theory.

It is possible to launch an artificial satellite to a libration point to collect information about cosmic rays and solar radiation and to serve as an intermediate station for distant space flights. Observations by such satellites would provide data for more accurate computation of the masses of the earth and moon. To effect such a launching a satellite must be accelerated to the escape velocity and then brought to a halt at the libration point. Of course, it is not easy to bring a rocket to a precise point in space at the very moment when its velocity is zero. Near misses, however, will not matter as the vehicle may "roll" into the pit and start oscillating around the libration point at a distance of some 380,000 kilometres from the earth.

STELLAR IDENTIFICATION CARDS

A policeman whistles, breaks squeal and the car comes to a halt.

"That'll mean a ticket for driving through a red light," he tells the driver.

"But the light was green."

"Are you colour blind?"

"No, but I'm a physicist and I assure you that at high speeds red light turns into green!"

The celebrated American physicist Robert Wood appreciated a practical joke and he liked pulling a person's leg, but he wasn't a liar. For the so-called Doppler effect can in fact turn red light into green, a physical phenomenon of which the policeman was probably ignorant.

If you have ever watched a train pass a station without stopping you will have noticed that as it passes by the pitch of its whistle suddenly seems to drop. The same thing happens when one travels towards a source of light. Light is carried by electromagnetic waves and, as with any other waves, the Doppler effect displays itself by a change in the "pitch"—the frequency—of the light. In this way red can well turn into green, as Wood tried to explain to the policeman. He only forgot to mention that for this to happen his car would have had to travel at 135 million km/hr and the policeman wouldn't even have seen him as he flashed by; he would have been on the moon within 10 seconds! But remote galaxies are receding from us with such speeds and, in fact, it was thanks to the Doppler effect that astronomers were able to detect this motion.

Every star has its identification card. This is its spectrum, a source of much important information from which astronomers determine the age, temperature, luminosity and chemical composition of stars. The chemical elements in a star's atmosphere make their presence known by leaving dark lines in an otherwise continuous spectrum (this is known as the absorption spectrum). When scientists studied the spectra of galaxies they found that in most cases the lines were displaced from their correct positions towards the red end. The inference is that the galaxies are receding from us at tremendous speeds. Mathematicians immediately computed that if this is so, then some 5,000,000,000 to 10,000,000,000 years ago they were all assembled in one place.

Actually, though, the red shift, as it is called, is in no way indicative of a "beginning of the world". It is wrong to transfer data concerning the observable universe to the whole of the universe. Next to our expanding region there may be other contracting and pulsating regions. The greater universe is endless in space and time. Matter exists infinitely, passing through countless changes, steadily evolving and never repeating the same stage twice.

Explorers from the earth will steadily penetrate deeper and deeper into this infinity, opening up one page after another. They will have with them in their space ships instruments which we cannot even imagine. But at least one will be based on the well-known Doppler effect. The astronauts will use it to determine their speed relative to different stars.

COSMIC UNITS OF MEASURE

The ancient Arabs used the thickness of a hair from the muzzle of an ass as a unit of length. Obviously, it depended on the individual qualities of the ass and varied from animal to animal. The ancient Mongols measured distances in terms of a day's journey on horseback. There was even less uniformity in such a unit, but it apparently suited the warriors of Genghis Khan. The yard, they say, was the distance from the tip of King Henry II's nose to the tip of the forefinger of his outstretched hand. The fathom was originally the distance between the finger tips of the two hands when the arms are stretched out in a straight line.

The distances involved in space travel evidently require bigger and better units of length. As long as we remain in the neighbourhood of the sun, visiting the moon, Mars, Venus or other planets, we could probably get by with kilometres, although the numbers would be rather cumbersome: 380,000 kilometres to the moon, 79,000,000 km to Mars or 5,780,000,000 km to Pluto. Distances beyond the solar system measured in kilometres would offer some tongue-twisting numbers, for instance 40,000,000,000,000 km to the closest star, Proxima Centauri.

Astronomers have therefore introduced units of their own. Firstly, there is the astronomical unit, which is the mean distance from the earth to the sun, i.e., the radius of the earth's orbit, and is equal to 149,500,000 km. Mars is 1/2 a.u. away, Pluto is 40 a.u. away, and the closest star is more than 250,000 a.u. away.

The next in order is the light year, which is the distance that light travels in one year at its speed of 300,000 km/sec. Thus, it is 4.3 light years to Proxima, and two million to the Andromeda Nebula.

There is also the parsec, a contraction of *par*allax *sec*ond, which is the distance at which the mean radius of the earth's orbit (i.e., the astronomical unit) subtends an angle of one second of arc. A parsec is 206,265 astronomical units or $3^1/_4$ light years. The diameter of our galaxy is only 30,000 parsecs. The remotest astronomically observed object in space is 2,000,000,000 parsecs away.

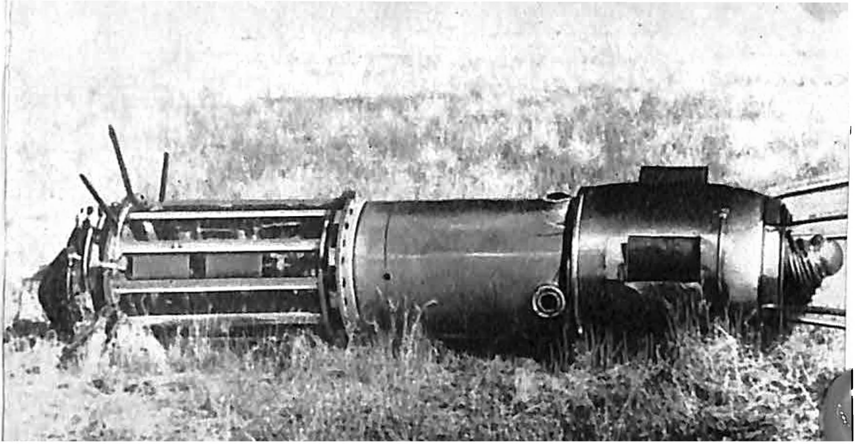
STAR CALLS STAR

In the spring of 1931 newspapers all over the world carried the sensational news that Karl Jansky, an American engineer, had received radio signals from outer space. The signals came in with remarkable accuracy every 23 hours 56 minutes. Many people wondered where the mysterious radio station was located: on Mars, or Venus, or maybe even near Sirius?

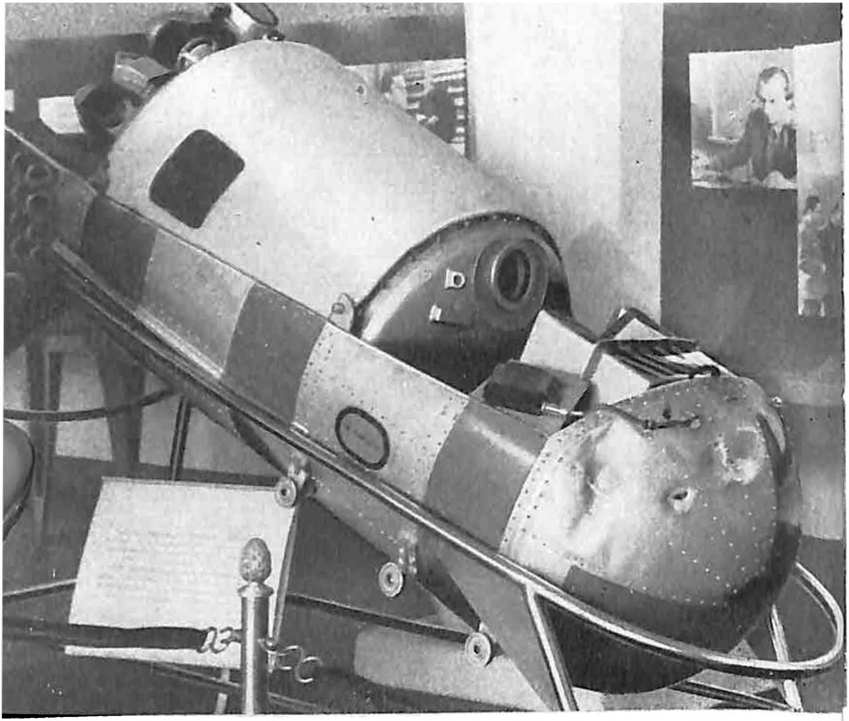
Then it was found that, although the radio signals did in fact come from outer space, they had nothing to do with intelligent activity. Their origin is as natural as that of the light coming from stars and nebulae. Matter emits electromagnetic waves of many kinds. The excitement died down and the phenomenon was forgotten, until the development and advances of radar techniques revived interest in it. During the war, for example, radio waves from the sun once caused flashes and oscillations on radar screens which alerted the whole of the British air defence service.

Investigation of the "radio sky" began immediately after the war. Huge radio telescope dishes were built to pick up the noises of outer space. The sun broadcasts on wavelengths ranging from 8 mm to 12 m. The moon communicates on 1.25 cm. Mercury, Saturn and Jupiter all emit radio waves. Natural radio signals have been picked up from objects thousands of millions of light years away.

Radio exploration of the heavens has resulted in an avalanche of discoveries. For centuries astronomers had explored the sky with the help of optical telescopes which could only pick up visible light. It was like studying the universe through a keyhole. Radio astronomy has opened up a wide window into the sky. Radio waves are invisible to the eye but they are audible to instruments and sounds perceptible to instruments can be made visible to the eye. Many new lights began to scintillate in the sky.



Rockets—geophysical, meteorological and others—were the first to break the path into space



This capsule brought the dogs Belka and Strelka back to earth from the orbit

In 1961, radio astronomers proceeded to map the contours of clouds of interstellar gas on stellar charts. These clouds are made up mainly of hydrogen. It was shown theoretically that hydrogen atoms in space should emit radio waves 21 cm in length. This prediction was brilliantly confirmed, and today we know not only the geography of interstellar clouds but also their velocities, temperatures and densities (for example, the faster the speed with which a cloud recedes from the observer the longer the wavelength of its radio emission).

Radio telescopes have been used to peer through clouds of interstellar dust blocking the light coming from different parts of the universe. Some truly remarkable discoveries have been made as a result. Thus, in 1961, it was found that the centre of our galaxy consists of a dense cluster of stars of very peculiar structure. Somewhat earlier radio astronomers confirmed the hypothesis of the spiral structure of the Milky Way. The visible limits of the universe have been extended three- and fourfold. Radio telescopes have penetrated to distances of 6,000,000,000 light years and discovered many new galaxies.

The radio emission of celestial bodies in the neighbourhood of the earth has also proved a source of many important discoveries. It is said that Mark Twain once sent a telegram in which he wrote: "Reports of my death are somewhat exaggerated." Well, the moon, it now appears, could send a similar message. Radio emission from it indicates that the temperature tends to increase below the lunar surface.

Hence, the moon is not a cold body. The powerful radio emission from Jupiter was found to come from a specific point on its disk. What is this natural radio source? Jupiter still guards its secret.

Radio astronomical instruments have been used to determine the distance to Venus with great accuracy, the temperature of its surface and its period of rotation.

Radio astronomy is a new and rapidly advancing science. Bigger and better radio telescopes are being built all over the world. The famous Jodrell Bank telescope has a parabolic bowl 250 feet in diameter. The antenna of a radio telescope at Pulkovo is made up of 90 flat sheets arranged in a 120-metre arc. Radio telescopes with cross arms one kilometre long have been built. Radio telescopes are used for communication with space vehicles, and since 1960 some astronomers have been carrying out a search for signals from intelligent beings in the neighbourhood of the closer stars.

UNIVERSE, RESPOND!

"Terrible is death in the fires of Hell, but pleasant is the fire of the hearth." Or, in other words, life inside a hearth is unenviable but by the hearth it is pleasant.

The authors of the old adage did not suspect that they had in fact formulated the gist of the problem of life in outer space: the fiery nuclear reactors of the stars warming the cold planets surrounding them.

How many planets are there?

The question is a difficult one, insofar as no terrestrial scientist has ever observed an "extrasolar" planet. At first there was merely confidence in their existence: "There are countless suns ... countless worlds.... These worlds are inhabited by living beings" (Giordano Bruno).

Only a quarter of a century has passed since scientists first interpreted irregularities in the motions of several close stars as being indicative of the presence of unseen planets.

An astronomer equipped with modern instruments and observing the solar system from the neighbourhood of the nearest stars might suspect the existence of Jupiter only under extremely favourable conditions of observation. The other puny planets would escape his notice altogether.

However, scientists know how to determine the speed with which stars revolve about their axes. They have found that stars of some spectral classes (including class G, to which the sun belongs) rotate tens of times slower than big and hot stars. This could be an indirect indication of the presence of planets; in a slowly revolving star most of the angular momentum has been absorbed by the attendant planets. Hence, rapid rotation is an indication of "planetless" stars.

There are 150,000,000,000 stars in our galaxy. Scientists have attempted to estimate the number of "planetary" stars. They eliminated the weak and unstable stars incapable of providing adequate heat for sufficient time to warm their attendants. They eliminated binary, triple and other multiple stars; the heat supply to their planets would fluctuate much too widely, depending on the configuration of the luminaries. From our point of view such fluctuations are unfavourable for life (from our point of view, of course).

According to Academician Fesenkov, the probability of life in the universe is about 1/1,000,000th. That is to say, out of every million stars there is one around which there may be revolving a planet with a terrestrial type of life. This means 150,000 inhabited worlds in the Milky Way. Professor Iosif Shklovsky estimates that this number could be increased to one million worlds where intelligent beings may be living at this moment. In this case several intelligent worlds should fall within our region of the universe (that is, within a radius of several tens of light years).

We continuously refer to life of a "terrestrial type", life based on carbon compounds and proteins. But what do we know of the physics and chemistry of life in the universe? We are still heatedly debating what life on earth is. We are still not agreed on whether viruses, for example, are "living" or "nonliving". What determines the development of living forms: only the conditions on a planet or cosmic factors as well?

Nature has allowed us to observe only one sample of life. We suspect that life may exist in some form or another on Mars and Venus. We find organic compounds in some meteorites. Mars and Venus are, of course, still problematic and as for the meteorites, it must yet be proved decisively that they did not gather the organic compounds from the earth's atmosphere.

As speculations develop, science and fantasy tend to merge. On the one hand, the most fantastic creatures are predicted, including living planets (!), living stars (!!) and even living galaxies (!!!) (according to the French astronomer and writer of science fiction, Camille Flammarion). On the other hand, it is suggested that we look for stars in the universe which appear to be sheathed in an artificial envelope: superintelligent beings would undoubtedly take steps to prevent their luminaries from wasting most of their light and energy in outer space.

The universe is infinite and so is the number of inhabited worlds. But is the diversity of life forms infinite?

We can discount planets populated with fantastic creatures by the science-fiction scribes. Let us also leave aside theoretical discourses on the possibility of an identical duplication of a terrestrial form of life on another planet.

I dream, as many times before,
That somewhere in another corner of the universe
I stand upon this selfsame shore
And with these selfsame stars converse.

Ivan Yefremov in his science-fiction novel *Andromeda** presents an "encyclopedia of worlds", inhabited or suitable for habitation. Among them are Epsilon Tucanae populated with a race similar to humans but more beautiful; Zirda in the constellation Ophiuchus (The Serpent Bearer) which perished because of uncontrolled nuclear tests; and a black planet near an "iron star" with some fantastic forms of life. He also speaks of signals, unintelligible even to the advanced civilizations of his book, coming from worlds lying close to the galactic nucleus, worlds whose inhabitants appear to have learned how to harness their luminaries.

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* Translated into English and published by the Foreign Languages Publishing House, Moscow, U.S.S.R., 1963.

And why not? The universe abounds in examples of both uniformity and variety. Nothing is unique: stellar giants, white dwarfs, planets, nebulae, dark clouds of gas, galaxies, stupendous stellar explosions—we find recurrence and reiteration in everything. The same temperatures, luminosities, speeds of rotation and conditions on planets can be observed over and over again. So why not the same forms of life?

On the other hand, however alike the objects of the universe may be, there are differences, and within our field of vision there are no two identical stars, planets or comets. Who knows how much "alike" or "unlike" inhabitable worlds may be?

But where are they, and how many are there? Why has no one ever visited our earth?

First of all, let us not exaggerate our own significance. As Captain Stormfield of Mark Twain's story discovered in heaven, his native planet was known there by the contemptuous name of Wart and completely forgotten to boot.

Secondly, we cannot just take it for granted that visitors from outer space have not been on earth. The several thousand years in which man has been writing and reasoning scientifically are but a fleeting instant to the universe. Astronauts who visited the earth thousands or millions of years ago could still be on their way home.

Thirdly, "we can assume," Professor Shklovsky writes, "that highly organized intelligent beings on some planet or other are keeping the dishes of giant antennae constantly trained on several (say 100) relatively close stars where, they think, intelligent life is possible, in the hope of picking up a reply signal. . . . We may well be . . . within a beam of electromagnetic radiation continuously being transmitted towards us by intelligent beings."

In April 1960, American scientists, in the presence of colleagues from the Soviet Union and several other countries, launched a "listening-in project" for signals from the stellar systems Tau Cetus and Epsilon Eridan.

These are neighbours of ours which bear a striking resemblance to the sun and possess planets. The signals were sought on a wavelength of 21 centimetres, which is considered the most suitable for cosmic communication (it is the wavelength of hydrogen radio emission, and hydrogen is the most abundant element in the universe).

Every six hours great radio antennae scanned the sky in the hope of picking up signals from distant worlds, signals denoting the numbers π or e or some other symbol equally understandable to advanced civilizations in any galaxy.

Huge reflecting antennae are being built. Scientists are becoming more optimistic and we are already getting impatient at the apparent lack of interest in us shown by the outer universe. But then, we may be a much greater freak of nature than we imagine. According to some recent estimates of the number of inhabited worlds in the universe there are only two or three "terrestrial" type worlds in the Milky Way.

Yet even so, there should be at least 1,000,000,000 terrestrial-like worlds in the observable part of the universe (the radius of which now stands at 13,000 million light years).

AN UNSOLVED MYSTERY

Since time immemorial Nature has confronted man with innumerable strange, mysterious and inexplicable things. One of the greatest and most provocative of these riddles is the Tungusska fireball. We deliberately do not call it a "meteorite", as the event that took place on June 30, 1908, in the neighbourhood of the Tungusska River in Siberia has not yet been explained satisfactorily in meteorite terms.

Many remarkable phenomena accompanied the event: a mighty blast of air circled the globe twice, the atmosphere darkened, and that evening dusk fell much later than usual in Central Europe. In the Caucasus the southern night was not black and velvety as it should have been but a ghostly white, as in the north, and one could read print without the help of a lamp.

In Irkutsk, Siberia, seismographs registered an unusual surface earth tremor at 7 a.m. and magnetometers showed sharp oscillations in the earth's magnetic field which lasted for several hours.

All this was caused by the Tungusska fireball. Early on a bright morning people saw it over an area of some 1,500 kilometres. A terrible roar and brilliant light caused everyone to look up. A white-hot sphere brighter than the sun was hurtling across the sky. It puffed a blast of wind at them, filled their hearts with fear and disappeared beyond the horizon, only to shake the earth with a deafening explosion of terrific force never heard before by human ears. The blast was heard a thousand kilometres away from the site of impact. Seventy kilometres away window panes broke, crockery fell to the floor and double shadows caused by the great pillar of fire danced on the walls. Forty kilometres away Ivan Petrov, an Evenk trapper, was thrown up into the air together with his animal-skin tent, wife and children, was knocked unconscious and lost his power of speech for several years.

Whenever people are unable to explain a natural phenomenon they either attribute it to God or develop a suitable theory. Thus it was with the Tungusska fireball. The superstitious Evenks decided that Ogdy, the great fire god, had come to punish them. He burned and felled the forest and killed their reindeer. They declared the site of impact taboo.

Many years later, after the revolution of 1917, people came to the site to investigate.

Many expeditions have been there since and many more will be dispatched. After a lengthy search the place of impact was found and the neighbouring region was studied. Calculations were made and conclusions and theories voiced. Nevertheless, to this day no one knows for sure what happened on the Tungusska River that summer morning in 1908.

If it was a meteorite then it must have weighed at least a million tons; only then could the friction of the air have caused the stupendous explosion which destroyed the forest within a radius of 25-30 kilometres, dug a crater 7-10 kilometres in diameter and melted the permafrost to a considerable depth beneath the layer of peat covering the ground. But if the meteorite exploded, where are its fragments? None have been found. The mysterious body has left no direct trace. Strangest of all, unfelled trees were left standing at the very centre of the explosion.

This, it should be said, is the greatest flaw in the meteorite explanation. So great, in fact, that it practically engulfs the meteorite.

Another theory is that the Tungusska catastrophe was a nuclear explosion, the wreck of a space ship from another world. The unfelled dead trees did not burn, they were charred as if by an instantaneous outburst of intense radiation. The opacity of the atmosphere, bright dusks and magnetic oscillations are reminiscent of phenomena following a nuclear test. Unfortunately, the latest investigations did not reveal any appreciable increase in radiation in the neighbourhood following the explosion.

It has also been suggested that it might have been a huge chunk of antimatter or a stupendous electric discharge—something as yet unknown to man, just as in 1908 people knew nothing of nuclear explosions and could not, naturally, suggest a nuclear explanation of the phenomenon.

The theory most favoured today is the cometary hypothesis; the Tungusska catastrophe was caused by an encounter with a cosmic iceberg. A comet with a nucleus of ice some 150 metres in diameter and a mass of one million tons would have evaporated so rapidly in the atmosphere that it would have produced an explosion like the one observed.

This theory was expounded at a conference on meteorites in 1964. The testimony of eye witnesses, descriptions of the state of the forest and other data were introduced to prove the point. It was concluded that the body had approached the earth from the east at an angle of 20 degrees to the surface. The orbit calculated from this would be typical for a comet.

This, of course, is very convincing, but the last word has not yet been said. Scientists are now beginning experiments with the aim of reproducing the event: the Tungusska catastrophe in the laboratory on the scale 1:5,000.

⋆ II ⋆

> And the wide heavens, starred and luminous,
> Out of the deep in mystery aspire.
> The strange abyss is burning under us;
> And we sail onward, and our wake is fire.
>
> FYODOR TYUTCHEV

MYSTERY PLANET

The earth is a fairly familiar planet. Yet it is still a mystery. The progress of mankind brings new knowledge and new ignorance—ignorance about things which were previously unimaginable.

Scientists have computed the length of the meridian: 40,008,550 metres. Pretty accurate, you will say. But who knows? Until we can be more accurate it is impossible to determine exactly the shape of the terrestrial sphere. For the earth is not a sphere but a geoid. (We shall discuss geoids later on.)

The most precise measurements will be made from satellites, and from outer space.

The area of the earth is 510,000,000 square kilometres, of which only 149,000,000 (29.2 per cent) is dry land. The Pacific Ocean alone could swallow all the continents. It all seems so clear—except for a couple of trifling points. Why is there so little dry land? And why is most of it in the Northern Hemisphere? The division is so uneven that years ago people were convinced of the existence of a great southern continent ("otherwise the planet would overturn").

Mount Chomolungma (Everest) rises 8,882 metres above sea level. The Mariana Trench in the Pacific Ocean lies 11,000 metres below sea level.

Where do the mountains come from? Where do the trenches come from?

Were the mountains piled up by inner terrestrial forces alone or did cosmic forces play a part as well?

Why the sudden glaciations?

Terrestrial science, it appears, answers the questions "what?", "where?" and "when?" much more readily than "why?" and "wherefore?".

The ocean depths are almost as unfamiliar as the Martian seas. The underground deeps are as little explored as the distant galaxies. When space flights began we found that we had overestimated our knowledge of the terrestrial atmosphere. Suffice it to say that its density at a height of several hundred miles was found to be ten times greater than assumed.

One can see more from outside. Some terrestrial features will be more apparent from the moon or Mars. The secret of the earth's magnetic field lies hidden far beneath the crust. The moon has no apparent magnetism. The answer to the riddle lies on Mars, Venus and other planets.

Life.... The earth receives 54×10^{33} (that is, 54 with 33 zeros) ergs of solar energy a year. Of this, fifty five per cent is absorbed by the atmosphere, soil, plants, living organisms, etc. Forty five per cent is radiated back. The earth's energy supply is sufficient to sustain in the atmosphere, waters and crust more than two million species of animals and half a million species of plants, to say nothing of 3,000,000,000 intelligent creatures.

We shall not deal with the numerous riddles of terrestrial life, or the problem of visitors from outer space, where the solutions to so many of them lie.

Our earth has shrunk considerably. It once took several years to circumnavigate it. Nowadays an astronaut circles the globe in 90 minutes. From the moon, Mars or Venus it will appear even smaller. But it is nevertheless ours, the only planet we call "home".

A GEOID IS A GEOID

Ignorance is a relative concept. Five hundred years ago people believed that the earth was flat and rested on three whales. Those who disagreed were hauled to the stake, so they were few. A hundred years later anyone could believe that the earth was spherical if he wished. Time passed, and people were again brought to task for such beliefs. They were not burned at the stake, to be sure, but a schoolboy declaring that the earth was a sphere would be given a poor mark. The model pupils quickly learned the lesson: "The earth is an ellipsoid of rotation; a sphere flattened at the poles." For when the earth was young and its crust soft and pliable the great centrifugal force of rotation pulled it out at the equator and compressed it at the poles.

The earth itself listened to these definitions in silence; it knew that it was not an ellipsoid, either. As scientists determined its shape more and more accurately they found that it was a more complex body, and they decided to call it geoid. They were not discouraged by the awkwardness of the statement "The earth has the shape of a geoid," which means "The earth has the shape of the earth." This definition, they said, was as good as any other and it described the earth's shape admirably.

It should be said that nowadays scientists are interested not so much in the configuration of the earth's surface as in the configuration of its gravitational field. Knowledge of gravity changes at different points of the planet can help scientists to penetrate beneath the crust and detect beds of iron ore, oil and other minerals.

The navigators of space ships sailing on the high seas of the earth's gravitational field must have detailed charts of its fluctuations. On the other hand, observation of artificial satellites tells scientists how they are attracted by the earth and helps them to determine its shape—though whatever new shape it may be found to have it will nonetheless remain a geoid.

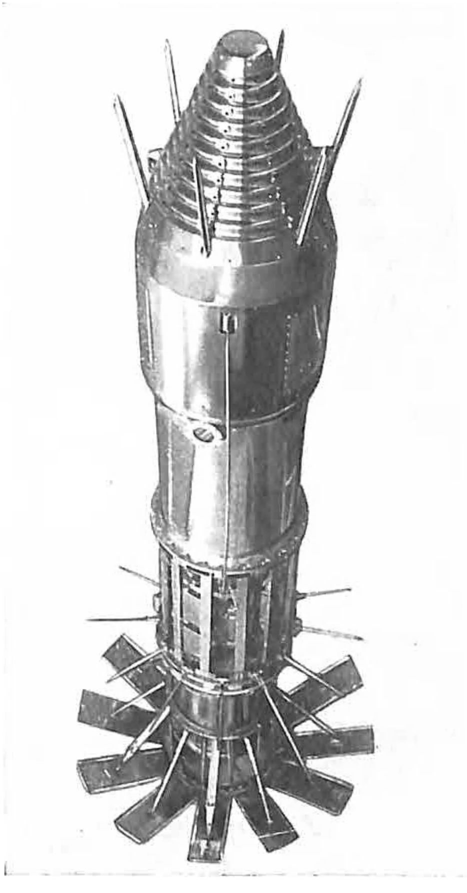
THE END OF THE EARTH

For thousands of years the thin, vague line of the horizon confused people, who thought that the earth was as flat as a platter. To them it was the end of the earth, beyond which lay Kingdom-Come, the land of bliss, the columns supporting the celestial sphere and the gate through which the sun came out to travel across the sky.

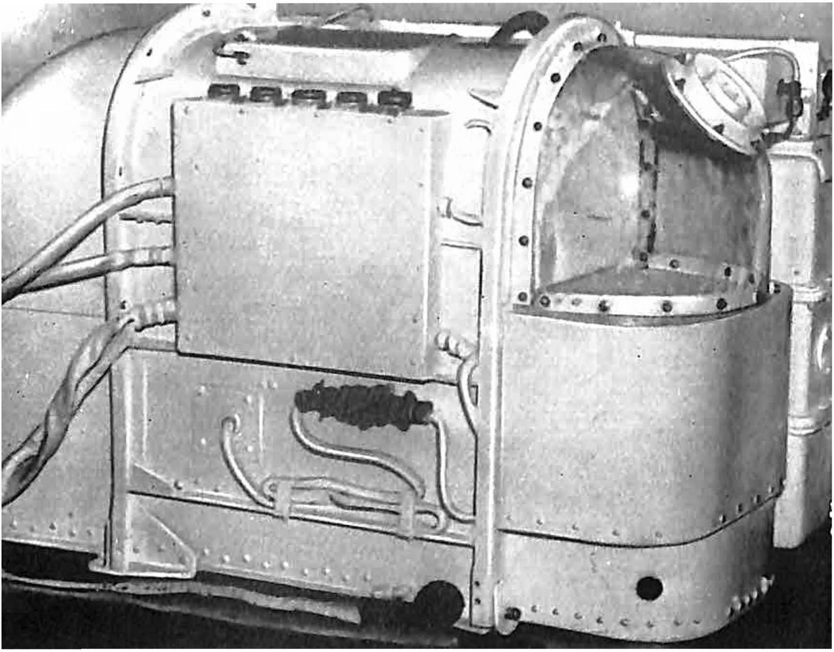
With stubborn determination Polynesian sailors travelled across the ocean "to the vague, hazy horizon which eternally retreats and eternally approaches, which inspires fear and beyond which no one has ever penetrated...".

The inquisitive Greeks, who claimed that in the evening one could hear the hiss of the hot sun dipping into the ocean beyond the horizon, did not risk going to see what it looked like.

However, by the sixth century B.C., when Pythagoras demonstrated the roundness of the earth, it became clear that there was nowhere to go, that the earth had no end and the horizon was simply the circle of the earth's curvature beyond which the eye could not see. In astronomy this boundary, inside which one can see the surface of the earth, is called the visible, or physical, horizon. It is distinguished from the mathematical, or true, horizon, which is the line along which the celestial sphere intersects the horizontal plane passing through the centre of the sphere, that is, usually, the observer's eye.



Each year rocket designers have to cope with new problems of ever-growing complexity



In space, too, the dog has remained man's devoted friend and assistant. It was dogs who first worked their way into radiation belts on board the satellite Cosmos-110 and continued orbiting there for several weeks

REJUVENATION OF CELESTIAL MECHANICS

Why doesn't the moon fall onto the earth and the earth onto the sun? How does one predict planetary motions? Why do day and night and the seasons follow each other in eternal succession? Why does the earth travel faster than Jupiter, and Jupiter faster than Pluto? How does one go about discovering a new planet without ever having observed it? What causes the tides? How are solar eclipses predicted? Why do we observe the stars and planets regularly while comets rarely reappear?

These and many other questions are answered by the science of celestial mechanics. There are young sciences only a few years or decades old. There are veterans which have been in existence for centuries. Celestial mechanics is one of the oldest. Even the approximate century of its birth is lost in history. Its creators are unknown. Its foundations were laid in ancient Greece by men whose names are forgotten. But the names of Copernicus, Galileo, Kepler and Newton will be remembered forever. They set out the basis on which the structure of celestial mechanics was built.

The great mathematicians of the 18th and 19th centuries, Clairaut, D'Alembert, Euler, Lagrange and Laplace, perfected the structure. They elaborated the basic theoretical methods which are used today to chart itineraries in outer space.

Today celestial mechanics is an applied science. It has been rejuvenated and supplies the answers to many new questions: the lifetime of an artificial satellite, the way to the moon, the best path to Venus and Mars, and so on and so forth. High-speed computers are now used to track satellites and compute the trajectories of interplanetary space vehicles.

A CHOICE OF WAYS

This is a stadium in which no umpire has ever pronounced the magic words, "Ready, steady, go!" In fact there are no umpires. The bright rays of the sun always flood its silent field and the same planets of the solar system run endlessly round the nine lanes: gleaming white Venus, sun-tanned Mars, striped Jupiter and Saturn.

There are no winners or losers in this race. Its outcome is preordained. Mercury runs on the inner track. Its orbit is the shortest, and it takes only 88 days to complete it. Pluto takes a thousand times longer to skirt the vast field.

The invisible lanes followed by the planets also differ in shape. Some are almost circular, while others are elongated like a slack noose. And yet the planetary orbits are uniform. Their planes are constant and only slightly inclined with respect to one another. The orbits of artificial satellites are much more diversified. They intersect at a great many angles and make a fanciful net girdling the earth. The orbits of the Soviet manned Vostok space ships were almost circular and inclined at 65° to the equator. The path of Luna-3, which brought back photographs of the far side of the moon, was a fanciful figure of eight embracing our natural satellite.

The orbits of remote planets attached to weird systems of two or three stars must be very complicated. The astronomers there, if they exist, must have a hard time computing them.

Motion in the universe is eternal and its forms are endless. Man contributes what he can. For it is only "God's ways" that are inscrutable. The ways of the skies above are both knowable and predictable.

FAR AND NEAR

It took a scientific revolution to produce the concept of the "aphelion". Copernicus had made the earth and the other planets circle the sun. But do they really circle it? For twenty years Tycho Brahe traced the course of Mars and cursed Copernicus, for the planet refused to follow a circle. It took Kepler nine years to compute its true path. He found that the planet travelled in an ellipse, with the sun lying at one of its foci. Hence the word "aphelion", which in Greek means "far from the sun", and denotes the point of an orbit which is most distant from the sun. There the tired planet slows down to gather strength to sweep in towards the sun again, to the "perihelion", which means "near to the sun".

As a planet approaches its perihelion it accelerates steadily and whips around the sun as quickly as possible. Venus, which moves in an almost circular orbit, is the most tranquil. The most erratic is Mercury, which approaches to within 46 million kilometres of the sun and then sweeps out to 70 million kilometres. Hot-headed and impetuous, Mercury rebelled against Newton's law of gravitation, and the old celestial mechanics was unable to explain why the longitude of its perihelion shifted by 42 seconds of arc a century.

But mankind does not begrudge Mercury its erratic behaviour, for observations of the precession of the perihelion provided one of the proofs of the general theory of relativity. Violations of laws, at least celestial, may occasionally be useful.

CELESTIAL COORDINATES

Where is the island of Sicily located? You must sail across the Mediterranean Sea until you reach the Apennine Peninsula, skirt it from the south, and there is Sicily. This is a wordy and highly inexact explanation. Sailors are much more to the point: so many degrees North Latitude, so many degrees East Longitude. These two numbers, the geographic coordinates, define uniquely the location of any spot on earth.

The simplest kind of coordinates are called Cartesian coordinates, after their inventor, Rene Descartes. Three mutually perpendicular intersecting planes yield three coordinate axes. Three numbers denoting three line segments measured off along the axes give a point in space.

But the reference planes need not necessarily be mutually perpendicular. They may lie at any angle, and then we have an oblique coordinate system. What if we take not planes but curved surfaces? They will intersect along curved lines. This gives a curvilinear coordinate system. You might well ask what useful purpose these manipulations can serve. The answer is that without them contemporary mathematics, with its tremendous potentialities, would have been impossible. Many different coordinate systems have been invented: spherical, cylindrical, etc. The solution of every problem is best carried out in some particular frame of reference.

The positions of the heavenly bodies are defined by means of celestial coordinates. Although the stars are different distances away from us, they all appear to be points on the surface of a black spherical dome. This is what is known as the celestial sphere, and although we are located at its very centre, we have no cause to be proud of this fact. This imaginary sphere is abundantly marked with equally imaginary points, lines and planes. Directly overhead lies the point called the zenith. A line drawn vertically downwards from the zenith intersects the celestial sphere at a point called the nadir. A plane drawn through our eye perpendicular to the zenith-nadir line intersects the celestial sphere along a great circle called the "true horizon".

The celestial sphere rotates as a whole, and all the stars except Polaris, the Pole Star, trace circles across the sky. Polaris is motionless. It marks the North Celestial Pole through which passes the celestial axis. The plane of the earth's equator is perpendicular to the celestial axis and cuts the celestial sphere along a great circle, called the celestial equator.

These imaginary points, lines and planes are essential for determining the locations of quite real heavenly points. Every star has its celestial latitude and longitude. In the horizontal coordinate system a star's "latitude" is its altitude, its angular distance from the horizon; "longitude" is its azimuth, the angular distance between the point of the horizon over which the star is located and the true south direction. In the equatorial system of coordinates, latitude (or right ascension) is the angle at which the star is seen above the celestial equator. The meridians (hour circles) pass through the celestial poles perpendicular to the celestial equator. Declination is measured in degrees, positive to the north of the celestial equator and negative to the south. Right ascension is measured in hours, minutes and seconds of time, such that $360° = 24$ hours.

Two coordinates provide an almost complete celestial address. All that remains is the distance. Nowadays even the layman is used to geographic references in terms of degrees North or South Latitude and East or West Longitude. Time will pass and people will grow accustomed to information stating that the location of a space ship is "7 hours 27 minutes 9.23 seconds right ascension, $+47°42'3''$ declination, distance 100 astronomical units".

A SHIELD OF GAS

This is the atmosphere. It protects our planet from overcooling and overheating. It weighs 5,000,000,000,000,000 tons. We breathe its oxygen, and plant life is nurtured by its carbon dioxide. It protects the inhabitants of the earth from the deadly hail of cosmic fragments that burn up in the air, leaving a glowing trail in their wake. Only the very largest reach the earth, wreaking havoc where they fall. Fortunately this happens only rarely. In short, our planet is encased in its atmosphere like an egg yolk in the white. Only this "white" has many layers.

In the lowest layer, the troposphere, which is 10-15 km thick, there is a continuous movement due to convection, and the mixing of cold and hot, moist and dry air; mists, clouds and thunderclouds are continuously being formed. This is the "weather kitchen".

At 25-30 km lies the stratosphere. Quiet and calm reign here. Then comes the mesosphere. At an altitude of about 80 km the temperature begins to rise steeply. This is what the scientists call the thermosphere, and which is more popularly known as the ionosphere. It is a bottomless sea of ionized gas, or plasma.

Broadly speaking, the atmosphere is a solution of oxygen (21 per cent) in nitrogen (78 per cent). As the percentages show, it is far from pure, and abounds in admixtures such as argon, carbon dioxide, hydrogen, helium, neon, krypton, methane, ozone (which, of course, is an allotropic form of oxygen), nitrogen monoxide and carbon monoxide. There is also a great deal of water vapour.

In separating us from outer space the atmosphere is both a friend and a foe. It burns up meteors but dangerously heats space launches; it protects us from harmful radiation but limits the resolving power of our telescopes. It is also useful for rehearsing the entry of space vehicles into the atmospheres of other worlds.

SOUNDING THE SKY

It is customary to make fun of weathermen. Every mediocre comedian has a stock of jokes about wrong weather forecasts. Nevertheless, it is thanks to the efforts of meteorologists and weather forecasters that the great world-wide fleet of air liners is kept airborne and on schedule.

Planes could not fly without information about the weather. The air ocean is always in motion, and many are its hazards and surprises: sudden thunderstorms, invisible air pockets and other dangers constantly endanger the frail aluminium winged creations of man. How nice it would be to soar out and above the surface of this ocean of air!

But would it be so nice? Would we find a friendlier environment up there? Hardly, for outer space has streams of charged particles and deadly radiation waiting for those who venture into its expanses. It, too, needs a meteorological service of its own. And like the sounding balloons used in the atmosphere, sounding rockets pierce the blackness of outer space. What can they tell us? Many things; about space dust, ranging from the minutest particles to specks of micrometeorites, and about clouds of gas moving out from the sun. The sun is the body primarily responsible for the "weather" in the space surrounding it. It radiates powerful streams of ultraviolet and X-rays, which are responsible for the earth's ionosphere. The reliability of short-wave radio communication depends upon our ability to predict the intensity of electromagnetic radiation from the sun.

The sun also greets space explorers with corpuscular radiation. The proton solar wind can also interrupt radio communication. But most important, streams of high-energy particles can have a lethal effect on space ship crews. If we can find the most dangerous "reefs" of outer space, the places abounding in lethal particle radiation and the rocks of meteor streams, cosmic navigators will be able to plot routes taking their space ships through the safer regions.

Meanwhile probes are being dispatched into the black void to sound its depths and erase the blank spots from the celestial charts. To be sure, these charts are still mostly blank spots. We still know very little about the regions lying outside the plane of the earth's orbit. Study of these regions is a task for future space probes.

Today a space launching is still a remarkable occasion. But the time will soon come when the cosmic "weather service" will be as commonplace as terrestrial meteorology is today. The cosmic weathermen will be sending in their reports across the expanses of outer space: "Flight conditions in neighbourhood of Jupiter favourable. Solar wind weak to moderate. No magnetic storms expected. Micrometeorite density within safety limits."

SPHERE OF LIFE

If we are to believe the Bible, the biosphere owes its existence to God's act of creation. He can hardly be very pleased with this creation of his, especially since some specimens in the primate family have even gone so far as to deny his very existence.

The biosphere is defined as that part of the envelope surrounding the earth in which life thrives. The term was introduced by Lamarck, but little used until the publication of a book on the biosphere by V. I. Vernadsky, member of the Academy of Sciences of the U.S.S.R. Much interesting information can be gleaned from his book, including the reason for mentioning the biosphere in the present volume.

Life, it appears, cannot exist without cosmic radiation. It is radiation that activates the matter of the biosphere and makes it blossom out into life. The earth owes its external appearance and the structure of its upper strata mainly to living nature. And living nature is the creation of external cosmic forces.

The principal source of radiation to date is the sun. Its radiant heat energy makes it possible for all creatures, from microbe and protozoon to

Homo sapiens, to enjoy the blessing of life. Incidentally, the bulk of living matter on dry land comprises insects, ticks, spiders and other invertebrates.

Man, like all other living creatures, is a product of the sun. The ancient sun worshipers were right when they attributed life-giving powers to the sun and ranked him above all other gods.

Like any other sphere (with the exception of the celestial sphere) the biosphere has its boundaries. They are rather vague and have been fixed by speculative reasoning and a few experiments. Inside the earth, the boundary of life does not descend below the 100° C isotherm; above it extends to an altitude of some 40 km. Higher up the radiant energy of the ultraviolet portion of the spectrum kills all living things.

Nowadays man's rapid advance suggests the need for revising these boundaries of the biosphere. If human progress continues at the same pace, the earth's biosphere will expand enormously, tending to bring the biospheres of other planets and the whole neighbourhood of the sun within its confines.

BELTS AROUND THE EARTH

It is getting harder and harder to make new discoveries on earth. Not so, however, beneath and above its surface. The first artificial satellites reported that at altitudes of 500-1,000 km the number of charged particles in space rises sharply—a thousand times at a height of a thousand kilometres. The earth is surrounded by charged clouds of varying density. The maximum density lies in the neighbourhood of the magnetic equator (which, incidentally, does not coincide with the geographic equator). Luckily, at the poles there are few particles. In this way nature has left man windows through which he can enter outer space.

The first discovery was followed by news of a terrestrial "corona"; the region of increased concentration of particles extends for some 50,000 km. This is seven or eight terrestrial radii. Then the density of the cloud sharply declines. The cloud is far from uniform inside, and scientists have concluded that the earth is surrounded by two charged belts.

One of them, the inner belt, lies fairly close to the earth and is generally restricted to the tropical zone. The other, outer belt, envelops almost the whole globe, and the concentration of charged particles is much higher than in the inner belt. The belts surround the earth like two huge concentric doughnuts. There are charged particles between the belts, too, but not many.

The origin of the earth's radiation belts is still open to speculation, but in any case the earth's magnetic field is evidently responsible for them. When magnetic lines of force are closed they trap charged particles. The earth's magnetic field works as such a particle trap. Sometimes the trap opens slightly and "prisoners" escape, giving rise to spectacular displays of polar lights.

The particles themselves probably come from outer space. True, some people say that the inner belt could be manmade, resulting from nuclear tests. The nuclear testing sites of the United States, Britain and France are located in the Southern Hemisphere. High-altitude tests conducted there released large quantities of radioactive debris. Their decay yielded fast electrons which penetrated to great heights and were captured in the magnetic trap. Only a few high-altitude nuclear explosions would have been needed to yield a radiation belt of the observed intensity.

PROTECTIVE OXYGEN

A man sits at a closed window. A hot southern sun streams through the glass. But, hot as it is, it does not produce sunburn. Open the window, and soon the man's skin reddens, even though the sun has not become any hotter. The conclusion is that glass is a shield against sun. What is the force that it keeps back?

Ordinary window glass is transparent to visible and heat rays. But it is almost completely opaque to ultraviolet waves, the invisible waves lying beyond the short-wave, violet, end of the spectrum. Fortunately, most of the ultraviolet waves are kept out by the thick layer of the earth's atmosphere. Fortunately, for if they reached the surface freely they would exterminate life on earth as they are lethal in large doses.

Ultraviolet waves are stopped by man's old friend, oxygen. At an altitude of 20 km or so oxygen absorbs them, turning in the process into a new, triatomic, state called ozone. Only a thin trickle of the sun's ultraviolet radiation reaches the ground. This trickle, far from being dangerous, serves many useful purposes. In small doses ultraviolet radiation is useful and even necessary for many organisms, man included. Some doctors even think that the windows of our homes should be made of a special glass transparent to ultraviolet rays.

On earth it is very difficult to study the ultraviolet radiation of outer space, so little of it reaches earthbound instruments. Sounding balloons and geophysical rockets have helped scientists to learn much more about it. Of late these investigations have acquired practical importance, as our space ships will be subjected to prolonged spells of intense ultraviolet radiation. Manned space flights to date reveal that the hull of a vehicle provides reliable protection against this hazard. As for the hothouses which will one day be built on artificial satellites, they will be provided with special windows to let through just the right amount of ultraviolet radiation needed for the normal development of plants.

STRIPPED NUCLEI

Ionization.

It concerns radio engineers.

An invisible ocean ripples round the globe from Pole to Pole. It is made up of radio waves, messengers of joy and sorrow, linking nations, cities and people. These waves, generated in radio stations, are radiated out into space by antennae. But people need them, and they return, reflected back by the ionosphere.

At high altitudes the atoms of the substances constituting the atmosphere are battered by fierce solar radiation which strips them of their electron shells. The electrically neutral atom turns into two charged particles, an electron and an ion. The atmosphere is surrounded by an ion shield that reflects radio waves back to the earth, whence they rebound up again. Like a ball bouncing between two parallel walls, they travel round the globe in this way to find their addresses. They enter wireless receivers and decay, having fulfilled their mission and transmitted the necessary information. When the sun steps up its activity this has an adverse effect on the ionosphere and radio communications are disrupted.

Ionization concerns physicists.

Plasma, the fourth state of matter, is the hope of electricity. Controlled thermonuclear synthesis, the fusion of two light atomic nuclei, cannot take place when they are surrounded by electrons. The electrons must be torn out of their shells, exposing the nucleus. Plasma, which is unstable, is born in powerful electric discharges and at tremendous temperatures.

Scientists fuss about the new-born substance trying to prolong its lifetime. Then they think of ionization, for this is how plasma is created.

It concerns rocket experts.

A force must be applied to lift a rocket. This involves ejecting a working substance from the rocket at high speed. The working substance is a gas, and a large amount of highly calorific fuel is needed. There is no other way of accelerating the working substance; it is electrically neutral and cannot be "hitched" to anything. But if its atoms are stripped of their electrons, charged ions result which can be accelerated by a magnetic field. If ejected from nozzles, they will drive an ion rocket into outer space.

A NEW DISEASE

Radiation sickness has accompanied many of the innovations of the 20th century. The most brilliant achievements of our age have been marred by its presence. The first victim was Marie Curie-Sklodowska. At the time doctors were unable to name the cause of her death. Her daughter and son-in-law, Irene and Frederic Joliot-Curie, also died of radiation sickness, a new disease brought into existence by X-rays, radioactivity and atomic energy.

Today we must add outer space and cosmic radiation to this list. Radiation sickness, which comes as a result of exposure to radiation and ionization, is a penalty of the new great discoveries. Long before the atomic bomb was even imagined, and before radiation sickness was known, Pierre Curie pondered over the evil aspects of his discovery.

"One can imagine that in criminal hands radium may be extremely dangerous. In this connection one could ask the following question: Is knowledge of the mysteries of Nature to man's advantage? Has mankind matured sufficiently to derive only benefit from such knowledge or is it also fraught with danger? Nobel's discoveries are a characteristic example: powerful explosives made it possible to carry out remarkable projects, but they are also terrible weapons of destruction in the hands of rulers who would drag nations into war.

"I personally belong to the type of men who reason as Nobel did, namely, that mankind will derive more good than evil from new discoveries."

Wilhelm Conrad Roentgen's dissertation was a single page: a page and a photograph of his wife's hand. It was not a common photograph, to be sure, but one showing the bones.

The great discovery of X-rays gave vision to medicine. Doctors could see a broken bone, an ailing joint, lungs, and even the cause of a cough. They could inspect the stomach and detect a cancerous growth in its early stages.

But after several years roentgenologists began to observe a strange kind of rash on their hands. Most of them complained of headaches. They were unable to work a full day and unaccountable physical and mental fatigue gripped them after several hours. They tended to become bald faster than their colleagues, therapeutists, surgeons or psychiatrists. The incidence of cancer and leukaemia was higher among them. Statisticians soon established that the life expectancy of a roentgenologist was on average five years less than that of doctors of other specialities.

Various explanations for this were proffered, such as the relatively high content of ozone in X-ray rooms. Then similar symptoms were observed among the makers of X-ray tubes, especially among the workers engaged in testing the finished tubes. Without yet understanding the nature of the danger, men began to device protective shields against X-ray radiation. X-ray screens were surrounded with lead shields. Roentgenologists were provided with heavy aprons and gauntlets of lead-impregnated rubber. A marked improvement was observed.

Only when the atom bomb was developed and two young scientists died after an accident in the American laboratory at Los Alamos, and when exposure to lower doses of radiation produced symptoms like those observed in roentgenologists, did the doctors realize that the new disease was a result of radioactive irradiation. The roentgenologists had suffered from the same disease, only to a smaller degree and in chronic form.

As long as cases remained few and isolated the state was described as "acute radiation syndrome". Not a disease but only a syndrome, that is, a group of signs and symptoms that always occur together. But after the A-bombs were dropped on Hiroshima and Nagasaki and atomic tests were carried out at Bikini Atoll in the Pacific Ocean, the syndrome was redefined as radiation sickness. Thus, unhappily, radiation sickness acquired legal status. It entered all the medical textbooks, handbooks and encyclopedias. Physicians studied it, learned to diagnose it and sought to cure it.

The effects of irradiation may tell at once, in several days or in several years, depending on the dosage received. Radiation dosage is measured in roentgens, and 600 roentgens is considered to be a 100-per cent lethal dose. Only it takes several days for the disease to become manifest.

Higher doses cause faster effects and extremely acute forms of radiation sickness. At 20,000 roentgens death is practically instantaneous. Small doses of radiation may display themselves in five or ten years in the form of leukaemia. Leukaemia is a disease in its own right, but after radioactive irradiation it occurs much more frequently. It is estimated that in Hiroshima the incidence of leukaemia among people who were within 1,800 metres of the epicentre of the A-bomb explosion was subsequently 15 times higher than that among the rest of the population. To this day Japanese newspapers report deaths as a consequence of the atomic blast in 1945.

All these delayed manifestations of radiation sickness in radiologists and the victims of atomic explosions represent either the chronic disease or its consequences. There are also acute forms in which symptoms display themselves immediately after a momentary exposure to radiation: headache, nausea, listlessness followed by an apathy and prostration. The initial period depends only on the initial excitation of the nervous system. The Soviet film *Nine Days of One Year* offers a good clinical picture of this period. A professor has received a lethal dose of radiation. He walks about the room, talks a lot and lays plans for further work. He knows his fate is sealed, but nevertheless continues to give orders and instructions. Suddenly he stops short. He sits down, draws into himself and doesn't look at the others. The depression stage has set in.

This is followed by a period of relative well-being, a "latent period", when the patient feels well and wants to leave the hospital. He has so much work to do and asks the doctor to let him go. However, laboratory data tell of the great struggle taking place within his organism. Soon the main stage of the sickness sets in.

All the blood-producing organs are inhibited. The organism no longer produces leucocytes, the white blood corpuscles that are our main protection against diseases. When a splinter gets under your skin leucocytes assemble from all parts of the body to fight the aggressor. They perish while erecting a protective barrier around the dirty splinter—the ring of inflammation surrounding it as its outward manifestation. In their very death they triumph and their dead bodies make up the pus. When an infection penetrates the body leucocytes surround the microbes and begin to devour them: Mechnikov called them phagocytes, from the Greek "phagein"—to eat.

As a result of radiation sickness the body begins to experience a shortage of these defence agents. From the normal 6,000-8,000 leucocytes per square millimetre their number drops to 3,000, a thousand, several hundred and even to several dozen. The organism is defenceless and may succumb to any infection whatsoever.

Burn lesions spread unchecked. Microbes, which till then had dwelled harmlessly in the mouth and bowels, begin to penetrate into body tissues with impunity and destroy them. Sores appear in the mouth, throat and intestines; gradually the man dies. He is in dire need of leucocytes, but their number continues to dwindle. Help can come only from outside. Donor leucocytes are injected into his blood stream. He is given transfusions of a blood extract with a high content of leucocytes. He is treated with antibiotics in the hope that they will protect him from the microbes. However, without the help of the organism itself it is very difficult to combat them. The body must be roused by some means.

And here doctors seek to exploit the very effects of radiation that are most harmful to the body. One method of curing leukaemia is the transplantation of bone marrow, one of man's principal blood-forming organs, so that it will function and produce new leucocytes, thereby overcoming the disease. Such transplantations become possible because the body's vital functions are suppressed and it is unable to resist the alien proteins. Thus it is the very weakness of the organism and its protective reactions that make the operation successful. As they say, like cures like.

Radiation sickness is one of the hazards of space conquest that must be taken into account along with cold, airlessness and the absence of pressure.

Another problem to be reckoned with is solar flares and the increase in radiation which they produce. One such flare occurred on August 14, 1962, during the flight of Andrian Nikolayev and Pavel Popovich, the Soviet cosmonauts. Luckily no increase in radiation intensity was observed either in the upper atmosphere or inside the space ships. Instruments continuously relayed to earth information concerning the radiation level, and the cosmonauts also kept track of the data. Should an increase in the radiation level have been observed the flight would have been terminated and the cosmonauts would have taken prophylactic doses of antiradiation drugs (even though they were additionally protected by the hulls of their vehicles and their space suits). Protection against radiation disease is an essential element in the Soviet manned space-flight programme.

SPACE EMBRYOLOGY

The sensation of flight through outer space is one of the most powerful that can be experienced in our age. Even though so far not more than a score of people have been in outer space and our impressions must needs be based on their reports, we are all, thanks to the efforts of scientists and astronauts, people of the space age. We have learned many things and can imagine a great deal for ourselves: not only the inimitable wonder of space flight but also the crushing G-loads during lift-off and re-entry, the terrific vibrations in the boost stage of flight, the hazards of cosmic radiation and the tricks of weightlessness.

Astronauts are people of excellent physique who are not inclined to nervous emotionalism or subjective exaggerations, and one can therefore rely on the unbiased quality of their reports. As for the wealth of telemetric information streaming down to earth from a space vehicle (or rather, from sensors and pickup leads located all over an astronaut's body to the electronic computers of the research coordination centre), its trustworthiness is beyond all doubt.

Today it is already clear that one does not have to be a superman to embark on a space flight. All that is necessary is good health and adequate training to prepare the organism for the surprises and hazards of outer space. Conditions of flight in a space ship are well known and scientists have learned to simulate most of them on earth. Nevertheless, each flight raises as many questions as it resolves, and more and more experiments are needed to answer them. Among them are biological, or rather space-biological, experiments, such as the following.

An embryo is a delicate, mysterious cell carrying the germ of a new life. Although Nature takes great pains to protect it, there is hardly anything more fragile and vulnerable. A normally developed adult organism is quite insensitive to things which are often lethal to an embryo. This sensitivity to environmental effects is used as a delicate instrument for studying space flight. Being susceptible to effects that may escape unnoticed in the astronaut's adult organism, an embryo can tell scientists much about the hazards of space flight. Furthermore, any damage it suffers is magnified tremendously as the embryo develops and is passed on to other cells of the developing organism.

It is very important to determine the degree of irradiation during a flight. In a live mouse, for example, a mean dose of 150 roentgens has a measurable effect. In an embryo an irradiation dose of 25-40 roentgens can be traced, and in an egg the effects of radiation can be detected even at 5 roentgens. This means that living embryos can be used as very delicate and precise instruments for studying the effects of radiation and the means of protection.

There is no difficulty in simulating G-loads. vibration and radiation on earth. Weightlessness can be simulated only for periods of less than a minute, and so on earth it is difficult to check an embryo's response to weightlessness. It has been suggested that the absence of gravity could kill an embryo. In a chicken egg, for instance, the embryo is usually located in the upper layer, above the yolk and just beneath the shell. In a state of weightlessness it has no means of orientation, may develop in any part of the egg and may even suffocate. For away from the shell the oxygen and carbon dioxide exchange may be cut off.

Another problem to be reckoned with is known in mathematics and biology as "biaxial and bilateral symmetry". Human embryos, like the embryos of other advanced organisms, develop along the lines of bilateral symmetry. One hour after fertilization the ovum develops the first distinction of a highly advanced organism: a second axis which biologists call the grey crescent. Half an hour later no amount of turning the egg can alter the position of the grey crescent, although before that it could move freely when the egg was turned. What determines the grey crescent's position? What is the mysterious mechanism that controls bilateral symmetry? And, finally and most important, what are the effects of terrestrial gravitation on the early stages of embryonic development?

These are the questions to be answered by space embryology, in experiments performed in conditions of zero gravity. Initial experiments, carried out with the eggs of nematodes, a parasitic worm, taken aloft on board the Voskhod-3 and Voskhod-4 space ships showed no appreciable effect of space flight on fertile eggs.

THE COST OF SAFETY

Cosmonaut 3, Andrian Nikolayev, received a radiation dose of around 50 millirads. Pavel Popovich, his partner in their twin flight, received 36 millirads. These are small, safe doses.

Myriads of invisible enemies—protons, alpha-particles, radioactive particles—traverse the universe in all directions, threatening men with radiation sickness, cancer and genetic diseases. They come from the earth's radiation belts, chromospheric flares on the sun and high-altitude nuclear tests. Before giving the green light to the Columbuses of outer space the scientists must ensure the radiation safety of space flight.

The ancient Argonauts passed between the Symplegades or Cyanean rocks—two cliffs that moved on their bases and crushed whatever sought to pass—by sending a dove ahead. The bird had its tail plucked by the rocks, and the Argonauts' ship slipped through almost unscathed while the rocks were rebounding.

The Argonauts of our time began by sending ahead a homely little plant called tradescantia (more commonly known as Wandering Jew), fruit flies and mice. Nikolayev and Popovich took up with them wheat grains, peas, cabbage, carrot and other seeds and even worm eggs. All these are biological radiation dosimeters with which, incidentally, both cosmonauts carried out important biological experiments.

Charged particles passing through the space ship hulls invaded the cells. The tradescantia chromosomes, which give the cell nucleus its colour and are responsible for heredity, reacted immediately to the radiation, and when scientists inspected them back on earth they could determine the radiation dose they had received. The natural dosimeters proved accurate to within 10 per cent of the physical instruments.

Fruit flies are classical organisms in the study of heredity and many important discoveries were made with their help. Some 1,000 fruit-fly genes affecting very different traits have been studied. Only males were sent up for the space experiment. This is because they transmit hereditary features to the first generation in breeding with normal females. The greater the number of changes lethal to the organism the lower the number of new males. Therefore the research workers' task was fairly simple; all they had to do was count the proportion of flies of either sex.

Flies, however, are far removed from man, which is why mice were brought into the tests. Not ordinary, but "inbred" mice. They are produced by inbreeding brothers and sisters through many generations. All the mice of one line, therefore, display the same hereditary characteristics. By comparing "space" mice with their brothers and sisters that remained on earth very small hereditary changes and physiological disorders can be observed (the latter were also studied, in the Soviet Union, on rats and dogs).

The biological pioneers of space flight have helped the scientists to determine the safe altitude of orbital flights. The day will come when astronauts will skirt the radiation belts and depart for distant worlds. But there, too, they may encounter deadly radiation. They will need lead screens several inches thick for protection. Such screens will also be useful in the event of solar flares; if they are used there will be no need to terminate an orbital flight.

THE STONE OF MAGNESIA

Legend has it that one day a shepherd pasturing his flocks in the hills of the ancient land of Magnesia, in Thessaly, observed that the iron tip of his staff was attracted by some rocks. The property of magnetite, or lodestone, to attract iron was also known to the Chinese, and more than three thousand years ago they called it "chi shih", which means "stone of maternal love". At school we are shown how iron filings arrange themselves in orderly patterns around magnets. One has but to sprinkle them on a sheet of paper or glass, place a magnet on the other side and gently shake the sheet for the filings to gather at the poles and stretch out between them, marking the magnetic lines of force. We also learned in school that electric current passing through a wire produces a cylindrical magnetic field around the wire, as demonstrated by the filings arranging themselves in concentric circles around the wire. Electricity can also be used to make magnets. One has but to place a steel bar inside a wire coil and pass direct current through the coil.

In ancient times the Egyptians thought that lodestone gave immortality. Galen, the great theoretician of ancient medicine, regarded it as a good laxative. The wise Avicenna used magnetite to treat hypochondria. In short, as Mark Twain put it, the knowledge which the ancients did not possess was comprehensive indeed.

Future generations may well say the same of us, for so far we can only conjecture as to the nature of the earth's magnetic field. Thanks to the works of the famous German mathematician Carl Gauss we know how to estimate its intensity when the latitude and longitude of a place are known. But we know nothing for sure about the sources of terrestrial magnetism. Some workers claim that there is a magnetic core inside the earth. Others say that this is impossible: the temperature down there is more than a thousand degrees Celsius, and magnets lose their properties at this temperature. They think that the magnetic field is produced by the rotation of the earth and that it is due to the rotation of electric charges scattered throughout the surface or volume of the globe. Many people make use of the magnetic compass but no one can explain why the magnetic poles "wander". Between 1948 and 1954. the North Magnetic Pole moved almost 150 km. In the earth's life time it has travelled all over the world.

In the age of space flight the study of magnetic fields has become an urgent problem. We must know what surprises the magnetic fields of outer space may have in store for future astronauts. Only after the first satellites and space rockets were launched were the earth's radiation belts discovered. They owe their existence to the earth's magnetic field. Evidently any planet possessing a magnetic field may be girdled with radiation belts. The crews of future space expeditions will have to skirt these belts, landing and taking off through the polar funnels where the radiation is weaker. The navigators of future space ships will be provided with charts of magnetic fields. Many of the lethal high-energy particles riddling outer space travel by spiralling along the magnetic lines of force. Knowledge of fields and their lines of force will enable the navigators to plot courses avoiding the hazards of radiation. Finally, the study of magnetic fields may offer a clue to the origin of galaxies. Some workers suggest that the spiral shape of the Milky Way and other stellar systems is due to the action of magnetic forces.

MAGNETIC STORMS

The famous English astronomer William Herschel refused to believe that the sun could be blemished by spots. He was proved wrong, and today we know that not only does the sun have spots but that they even follow a regular 11-year cycle from maximum to maximum. At these maxima many interesting phenomena can be observed on earth. The intensity of the earth's magnetic field and the disturbances it undergoes fluctuate according to the same pattern. Some deviations from the normal are so great that they are called magnetic storms. These storms, like atmospheric storms, are fraught with danger for ships at sea and aeroplanes in the sky as they disrupt short-wave radio communications and the craft "go blind". A magnetic storm hits the ionosphere and disrupts its normal structure. The earphones of radio operators begin to splutter and crackle with static. A magnetic storm is always accompanied by an electric storm, and electric currents begin to flow through the earth. They are so powerful that they may even disrupt the work of telegraph lines.

Magnetic storms are also accompanied by spectacular auroral displays around the poles. Scientists found that the polar lights, too, appear during maxima of solar activity. Streams of corpuscles are ejected from sunspots with tremendous speeds. They invade the earth's magnetic field, wreak havoc in the ionosphere, spiral along the lines of force to the poles and cause the colourful lights so familiar to inhabitants of the far north. They ionize the rarefied gases of the upper atmosphere, which begin to glow just like the rarefied gas in a neon tube. During especially strong magnetic storms the aurora may be observed far into the temperate zone. Soviet scientists noticed back in the 1930s that the more intense a magnetic storm the more spectacular the polar lights.

Today some 60 geophysical stations scattered all over the world, from the Arctic to the Antarctic, are studying the earth's magnetic field, measuring terrestrial currents and observing the sun.

★ III ★

The scholar's ink deserves as much
respect as a martyr's blood.

EASTERN ADAGE

TEN DAYS BEFORE EXECUTION

He dreamed of liberating all men from social oppression and the eternal shackles of the earth. He was a revolutionary in politics and in science. And he was sentenced to hang at the age of 27.

They say that a man's life is determined by actions that transcend the boundaries of the commonplace. Nikolai Kibalchich considered that there was nothing surprising in his fate: whatever happened to him should have happened, and he could have forecast it in advance. He was a student of the Institute of Railway Engineers and later of the Medico-Surgical Academy in St. Petersburg, a man of lofty soul, moral integrity and precise logic. He did not hesitate to join the revolutionary movement and throw in his lot with the Russian Narodniki, or Populists, and their party, Narodnaya Volya (Popular Will).

His speech at his trial was like a well-reasoned lecture to an audience of scholars. Calmly and consistently he outlined the goals of the Populists and their reasons for resorting to terror. Equally calmly he told of his participation in the attempted assassination of the Tsar and how the mine planted by him derailed the Tsar's train in 1879. Unfortunately, the Tsar had not boarded it. But then, on March 1, 1881, his bomb, thrown by Grinevitsky, finally caught up with Alexander II. If the government had done anything to improve the people's lot, Kibalchich said, "we should not be standing here accused of regicide.... Instead of producing projectile weapons I should certainly have directed my inventiveness to the study of handicrafts, the improvement of farming and the perfection of farming implements."

Revolutionary activity called for action and left little time for scientific research. Kibalchich had only two weeks of really "free" time: in his death cell. Two weeks to complete and formulate his ideas of a steerable aircraft. Two weeks to write his scientific and engineering testament. They proved sufficient to make his name famous.

At that time aeronautics was in an embryonic stage. Having learned how to ascend into the air in balloons, people could devise no way of controlling them. Kibalchich dreamt of a steerable apparatus heavier than air. He worked hard to consider all aspects of the problem and to carry out all the necessary calculations. The main thing was the idea; the experimenters and engineers would do the rest.

"When I went to see Kibalchich," his lawyer said at the trial, "I was struck by the fact that he was engaged in something that had nothing to do with the trial. He was preoccupied with his idea of an aeronautical apparatus; he wanted to be given the opportunity to write down his mathematical investigations of his invention."

What force would lift his apparatus? Steam? Electricity? They were unsuitable. Gunpowder would do the job; he knew its potentialities only too well. The next step was to harness the energy of the gases released in the burning of the explosive. This was possible only if the energy output could be produced over a sufficient period of time and not instantaneously. This was achieved in a firework rocket by burning pressed gunpowder. A rocket, not Jules Verne's cannon, could open up the road into outer space. Actually Kibalchich's design was of a space ship, not an aeroplane, as it could travel in outer space. Ten days before his execution, on March 23, 1881, he handed over to his lawyer his "Design of an Aeronautical Apparatus".

"When I was free," he wrote, "I did not have time to elaborate my idea in detail and prove its feasibility by mathematical computation.... I am writing down my project in prison, several days before my death. I have confidence in the feasibility of my idea, and it is this confidence that supports me at this time. If, after a thorough analysis by expert scientists, my ideas are recognized to be feasible, I shall be happy to have rendered a great service to my country and to humanity. I shall go calmly to my death in the knowledge that my idea will not die with me and will live on for the benefit of humanity, for whom I am ready to sacrifice my life."

The authorities promised to have the project studied. Kibalchich waited for an answer. On March 31 he wrote an appeal to the Minister of Internal Affairs. It was not an appeal against his conviction or for clemency but a request for a meeting with a scientist, or at least a written conclusion from an expert commission. This final document in Kibalchich's dossier bears the note: "It would hardly be opportune to submit this to expert opinion as it would cause nothing but undesirable gossip."

One of the boldest scientific and technological ideas in human history remained buried in the police archives for 36 years, until the October Revolution of 1917.

IT ALL BEGAN WITH A TOY

Our time is sometimes called the rocket age, although in fact the rocket is a much older invention than the electric motor, internal combustion engine or even the steam engine. In fact, it appeared many centuries ago in the east and in its childhood took part in many spectacular firework displays at popular festivities.

As it matured the rocket appeared in the battlefield, while also continuing to be used as a toy. In Russia in Peter the Great's time a one-pound signal rocket was used in the army, and it remained in use to the end of the 19th century. It could reach a height of 1,000 metres.

Military rockets designed by Konstantinov, Zasyadko and Kongrev were used in several armies.

At the beginning of the 20th century Tsiolkovsky brought out his treatise *Exploration of Outer Space with Reaction-Propelled Apparatus*. Meshchersky elaborated the fundamentals of rocket dynamics. Then there appeared the works of Tsander, Goddard and Obert. Finally, in the nineteen-twenties, the first liquid propellant rockets were built and new theoretical investigations were carried out. Rocketry began to progress rapidly, like so many other scientific and technological breakthroughs of the 20th century. The progress of rocketry in the last 30 years is immeasurably greater than in all the preceding centuries.

Today the family of missiles and rockets is large and varied, with special designs for particular duties. The most celebrated members of this family are undoubtedly the huge rockets whose powerful motors are capable of overcoming the pull of the earth's gravity. The younger brothers of the conquerors of outer space carry out less spectacular though equally important jobs at lower speeds and lower altitudes. Geophysical and meteorological rockets bring back information about conditions in the upper atmosphere, the earth's magnetic field, cosmic rays, the earth's radiation belts and clouds. Rockets are used to forecast the weather and to change it. Experiments have been carried out in which rockets spray chemical substances in thunderclouds to make them precipitate rain instead of harmful hail. Unfortunately, not all rockets are designed for such beneficial purposes....

But what does a rocket consist of? Hull, motor, propellants, instruments and, last but not least, the payload. The cylindrical bodies of rockets are made of light but sturdy materials, such as duralumin, titanium and, occasionally, plastics.

Most rocket motors are of the liquid propellant type. In outer space there is no oxygen and a rocket must therefore carry both fuel and oxidizer. Fuels include alcohol, kerosene and other highly calorific substances; oxidizers include pure oxygen, nitric acid and other chemicals.

Some rockets have solid propellant motors in which the propellant comes as a ready-to-use mixture of fuel and oxidizer, usually powders of different types. Intense research work is now being conducted on new types of solid propellants.

The maximum attainable velocities with both liquid and solid fuels are not very great, and they may well prove to be a handicap in exploring even the solar system. The rocket men are therefore busy devising new propulsion systems in which the propellant does not burn. For, according to the principles of rocket propulsion, the important thing is not to burn the fuel but to throw back a very fast jet, to accelerate the so-called working substance.

An electric field can accelerate ions, which are charged fragments of atoms produced in special generators. This is the principle embodied in the ion motor. A plasma motor uses an electric and a magnetic field to accelerate a plasma, which is a mixture of electrons and ions. In a nuclear-powered motor the working substance is heated in the reactor and ejected through a nozzle or nozzles. Finally, there is the most ambitious project of all; a photon motor which ejects a powerful stream of photons, or light corpuscles. Out of all these types of rockets those nearest to completion today are the ion, plasma and nuclear motors, which will probably soon find a place in space ship propulsion systems.

In fact electrical jet plasma motors were tested on the Soviet Zond-2 space vehicle, and ion motors were tested on the three-man Voskhod space ship.

IN A CHARIOT FILLED WITH ROCKETS

He was a man of quick wit, quick pen and quick sword. He hated conceit, bigotry and ignorance. His stinging satire knew no mercy and its darts spared no one, be it a puffed-up, lionized singer, a humble Jesuit or the insinuating Cardinal Mazarin himself. Naturally, he had many enemies. They forgave him neither his satirical barbs nor his free thinking. He died from a blow dealt treacherously from behind.

But two and a half centuries later his voice again came to life:

> Freedom is my cloak
> And courage is my plume,
> And thus I follow my straight road
> And truth rings louder than spurs wherever I go!

The French writer and soldier Savinien Cyrano de Bergerac returned to world-wide fame in Edmond Rostand's heroic comedy. Since then the dashing cavalier with the long nose and gleaming sword has been pacing the stages of the world. It was of him that Gorky wrote to Chekhov: "That is how one should live, like Cyrano."

Poet, playwright, soldier, philosopher, pamphleteer, duelist—it is hard to say to what in particular he owes his fame. His incredible bravery astounded even the Gascons of his company who, if we are to believe Dumas *père*, never praise anyone but themselves. He vied with Corneille and Moliere in drama. He was a contemporary of Thomas Moore and Tommaso Campanella, and created a Utopia of his own (*The States and Empires of the Moon*) inhabited by giants 12 cubits tall who walked on all fours and used verse instead of money. But to reach that remarkable country one had to solve the problem of interplanetary flight. And Cyrano, ridiculing the scholastic spirit of the time, offers with mock seriousness a number of very "scientific" methods: one could girdle oneself with bottles of dew (which, as everyone knew, was attracted by the sun), smear oneself with the brains of an ox, or build a magnetic vessel and toss up an iron sphere to attract it. His boldest (and, from his point of view, possibly the most far-fetched) method was to fill a chariot with rockets and propell it by fireworks. But it was for this method that Cyrano de Bergerac was later proclaimed a prophet and why he deserves a place in this book.

"TOWARDS IMMORTALITY AND ETERNAL YOUTH"

"The best thing on earth is travel," according to the testimony of a man who knew "but one, all-consuming passion". It drove him to the bottom of the sea, into the skies and down into subterranean deeps. Four times he circled the globe, almost died of thirst in the desert and shivered with cold at the North and South Poles. One can envy him and follow him through hundreds of pages and thousands of miles of remarkable travels. Your guide is Jules Verne, the remarkable dreamer of dreams come true.

Human fantasy is thousands of years old. The history of the human race is also a history of human fantasies, which once provided Icarus with wings and the Thief of Bagdad with a flying carpet. Today it has produced rockets and satellites.

The dreams of the ancients are colourful, fantastic . . . and helpless. Their imagination carried them away on the wings of fancy but they had no support under their feet. They populated the world of their imagination with gods and demigods. Man could do no more than envy them. And if he got too daring—well, we all know the fate of Icarus.

The beginnings of scientific romance can be traced to the 16th-18th centuries, when the characters of many novels reached the moon with migratory birds, fell asleep to awake several centuries later, enjoyed a life of bliss in utopian lands and travelled nonchalantly from planet to planet. In short, they contained all the attributes of scientific romance except sober science. Their fantasy was too fantastic, with no hope of ever coming true.

Jules Verne was the first to develop the genre of really scientific romance, a realistic fantasy in which both feet were planted firmly on the ground.

The 19th century was much faster moving and energetic than its predecessors. An avalanche of discoveries and inventions suddenly engulfed an unprepared humanity, toppling many of its fundamental notions. The globe shrank in size while the human mind gained unprecedented power.

It began to penetrate into the secrets of matter and discovered new laws of the universe.

It created the electric motor and the telephone, the aeroplane and the photographic camera, the steamboat and the telegraph, the automobile and the cinema.

It described the properties of undiscovered elements and the motions of undiscovered planets.

Jules Verne was a product of his age and its prophet. He forecast the submarine, aeroplane, sound cinema and rocket techniques. Yet he wrote: "Whatever I may have made up, it will prove to be inferior to reality, for the time will come when the achievements of science will surpass the powers of the imagination." This time came much sooner than anyone could have expected. In 1873 Jules Verne travelled around the world in 80 days. In 1936, the French author Jean Cocteau repeated the journey. But he had to travel slower than he need have to take as many days.

In the words of one critic, "The most remarkable thing about Jules Verne's novels is that today there is hardly anything remarkable in them." Jules Verne was sure that the day would come when his machines and devices would be hopelessly outdated. But he also believed that man would penetrate to the depths of the earth, to the bottom of the ocean and into outer space. His confidence stimulated others.

Simon Lake, designer of submarines: "Jules Verne was the guiding light of my life."

Alberto Santos-Dumont, aeroplane and airship designer: "He taught me never to lose faith in ultimate victory."

Admiral Richard Byrd, polar explorer: "I was led on by Jules Verne."

Mendeleyev called him a scientific genius. He was a genius of vision and popularization. He leads his readers into laboratories and workshops and rains upon them a wealth of information about physics, astronomy, biology, geography and mathematics. He shows, explains, convinces, and smiles.

Hector Servadac, *Upside Down* and *Chasing a Meteor* are astronomical escapades based on wholly impossible surmises from which, however, subsequent events follow with inexorable logic, according to the principle, "what would happen if...".

Two thousand years after Archimedes' time his enthusiastic followers did find the elusive "place to stand on" and attempt to move the earth's axis by 23°28′. Impossible? But here is what would have inevitably followed....

The earth collides with a comet and a piece of Africa is hurled into outer space, only to return a couple of years later and fall precisely into the place from which it had been ejected. Nonsense? Of course. But does the reader regret the journey? He has seen many things and has surely not been bored.

His most criticized novels are probably *From the Earth to the Moon* and *Around the Moon*. Mathematicians, physicists and astronomers have exposed his mistakes and accused him of ignorance. To be sure, from the scientific standpoint the idea of travelling to the moon in a projectile shot from a cannon doesn't hold water. The passengers would be crushed by the acceleration and the projectile would simply not reach its destination as no known explosive would be capable of giving it the escape velocity. But in the middle of the 19th century it was the only way of overcoming the earth's gravity. It would hardly be fair to blame Jules Verne for not considering rocket propulsion.

However, let us hear what one of his heroes has to say. To prevent the projectile from crashing into the moon's surface he suggests the use of rockets which, "supported by the bottom of the projectile and flying out would produce a motion opposite to that of the projectile, thereby retarding the velocity of its fall to some extent." This sentence contains perhaps the most remarkable scientific idea of the novel. As in other instances, Jules Verne's contemporaries overlooked it.

Jules Verne was a visionary and a poet, a poet of science. The plots of his novels are set in the solar system. Their content is the quest for truth and the struggle of scientific ideas.

As for his heroes, in the words of a French critic, "There is that in his novels which will never become outdated or lose its value; the soul of his heroes." He brought the scientist into literature. Not a helpless, absent-minded, lone traveller, not a man enveloped in clouds of tobacco smoke in his ivory tower, but an inventor, a creator, a man of action, courageous, noble and strong, transforming the earth, creating fantastic machines, and conquering space and time.

"There are no unsurmountable obstacles," says Captain Hatteras as he hacks his way through the arctic wastes to the Pole.

Robour flies up in a heavier-than-air vehicle.

Captain Nemo conquers the submarine world.

Michel Ardan escapes the earth's gravity and flies to the moon.

These are roads into the future.

"Towards immortality and eternal youth" is inscribed on a statue of Jules Verne. Towards the immortality of the human intellect. Towards the eternal youth of the human spirit, towards fantasy and vision! For, as Jules Verne himself says, "everything great that was ever created in the world was engendered by creative thinking."

The time will come when an astronaut carrying a volume of Jules Verne will sit on the edge of a lunar crater called Jules Verne.

FROM KALUGA TO OUTER SPACE

That day millions of T.V. sets all over Europe were tuned to Moscow. The screens showed joyous crowds in the streets of the Soviet capital hailing the Columbus of the universe, the world's first cosmonaut, Yuri Gagarin. Many people watching the hero's welcome given to Gagarin in the Red Square naturally turned their thoughts to Konstantin Tsiolkovsky, scientist and dreamer, theoretician of space flight.

Konstantin Tsiolkovsky, founding father of the science of space flight, was born in September 1857, just one hundred years before the first artificial satellite began circling the world. As a result of an attack of scarlet fever in childhood his hearing was greatly impaired and he had great difficulty at school, leaving after the third grade. He began studying by himself and was especially drawn to mathematics and physics. In spite of his handicap he successfully passed the examinations to become a schoolteacher of arithmetic and geometry.

Eighty years separate Gagarin's flight from the first notes made by the provincial schoolteacher dreaming of the conquest of outer space. The progress since then, slow at first, has in our time gained tremendous impetus. Alone with his thoughts, Tsiolkovsky let his fancy soar freely to dizzy heights. It carried him scores of years into the future, painting pictures of the space age of today and tomorrow. He had the gift of truly prophetic vision. At the time when he was describing exciting interplanetary journeys of the future there were not even any aeroplanes, to say nothing of rockets. Yet Tsiolkovsky forecast multistage rockets, automatic rocket steering systems, orientation according to the sun in outer space and heating in the atmosphere during re-entry. He wrote of the possibility of other worlds being inhabited by intelligent creatures quite unlike human beings. Tsiolkovsky's paper in the *Kaluzhsky Vestnik* (Kaluga Herald) anticipated communication with extraterrestrial intelligence by means of the universally understandable language of mathematical concepts. He invented gas rudders for steering rockets in the atmosphere and in outer space.

Tsiolkovsky's inventiveness was inexhaustible, and it is hardly surprising that as far back as the 1920s many scientists and engineers, including another grand old man of rocketry, Hermann Obert, sought information and advice from him. Even Albert Einstein was interested in Tsiolkovsky's work.

Many were the ideas that came from the modest, retiring schoolteacher from Kaluga. His pupils and followers have built the world's first space ships. It is opportune to recall his prophetic message, broadcast by radio on May 1, 1933:

"Greetings to you!

"I am picturing the Red Square in Moscow. Hundreds of steel birds fly over the heads of the marching columns. . . .

"The air is getting crowded with steel birds. This has become possible only now, when our Party and Government, the whole of our working people, and every working man of our Soviet land have pooled their efforts to carry out man's most daring dream, the conquest of the heights above the clouds. . . .

"And now, comrades, I am confident that my other dream, interplanetary travel, which I have substantiated theoretically, will also become a reality.

"I have been working on reaction propulsion for forty years, and I thought that trips to Mars would begin in hundreds of years. But the rate of progress changes. I am sure that many of you will witness the first flight beyond the atmosphere."

"WOULD YOU FLY FIRST?"

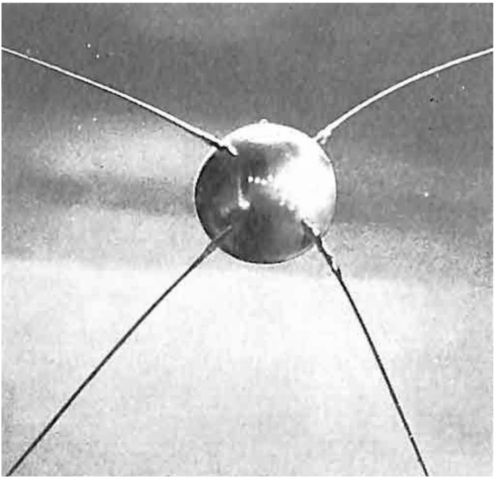
In the town of Kislovodsk, in the northern foothills of the Caucasus, there stands an imposing red-granite statue of a man whose contributions to modern rocketry were great and varied. His thin, somewhat ascetic face looks down on the passer-by. Above a grid of meridians and parallels covering the contours of a globe is a stainless steel rocket pointing skywards.

The man buried beneath the statue died on March 28, 1933. On November 25 of that year the rocket ГИРД-X, a replica of which adorns the base of the statue, was mounted in a launching frame in a field not far from Moscow.

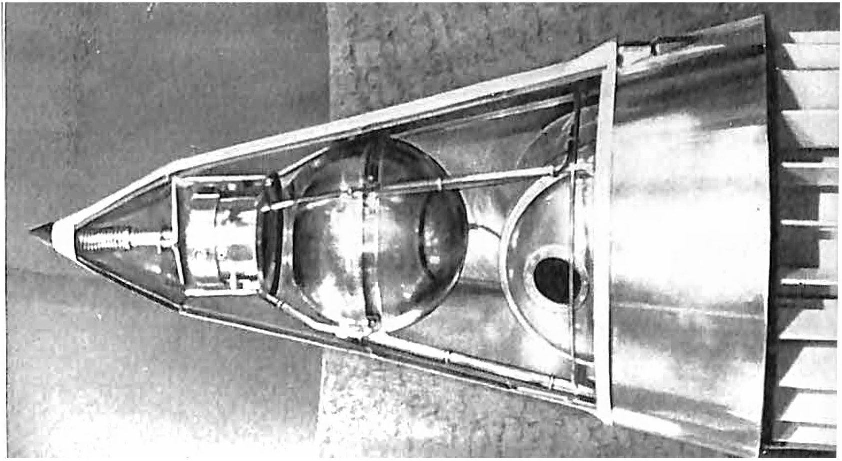
"Fire!" came the command. The motor roared and the rocket to which Friedrich Tsander had devoted so much strength and energy soared into the sky.

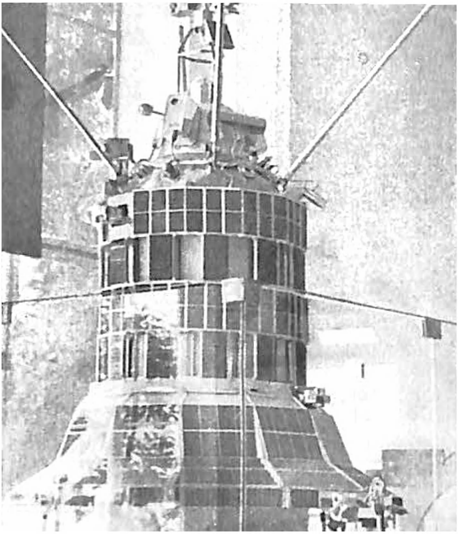
He lived only 46 years. "Forward, comrades, forward," he wrote to his associates from his deathbed. "Lift our rockets higher and higher, closer to the stars."

When he was a boy his father, a doctor of medicine, told him exciting stories about other planets possibly inhabited by strange creatures. It was then that he began to dream of interplanetary flight, a dream which, as he wrote later, never left him. In 1903, as a sixteen-year-old schoolboy, Tsander read Tsiolkovsky's *Exploration of Outer Space with Reaction-Propelled Apparatus*. Five years later Tsander, by then a college student, spent all his savings on a telescope. In 1909 he became one of the founders of the Students' Aeronautical and Flight Technique Society at the Riga Polytechnic. He began to put his ideas into practice, thinking up unusual things and immediately proceeding to make them.

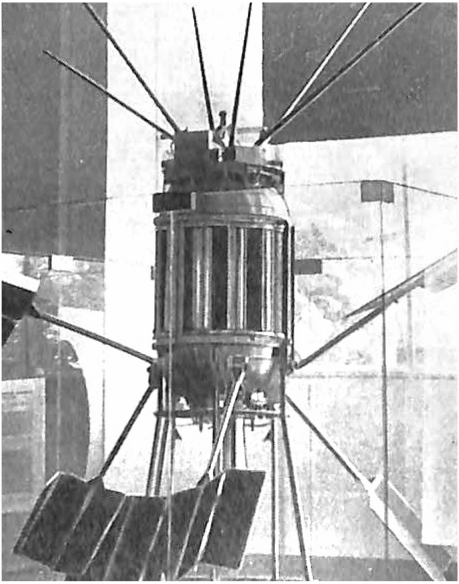


World's first and second earth satellites. This is history now





One and the same rocket launches Electron satellites into different orbits to probe radiation belts simultaneously



Tsiolkovsky wrote about greenhouses in outer space.

Tsander filled flower pots with crushed coal and grew peas and cabbage.... One can launch a rocket-plane and after it has passed through the atmosphere burn off its wings which are no longer needed.... Rays from the sun can be caught in giant mirrors and reflected to the spacecraft....

The world's first organization devoted to space exploration, the Society for Studying Interplanetary Travel, also owed its existence to Tsander. Later he headed the Technical Council of the Group for Studying Reaction Propulsion and Rocket Flight (the Russian abbreviation of which gave the ГИРД rocket its name).

When, in 1959, Luna-3 circumnavigated the moon and photographed its far side Tsander's associates had another occasion to remember him. The calculation of the flight trajectory carried out in 1957 by V. A. Yegorov and published in the journal *Uspekhi Fizicheskikh Nauk* (Achievements of the Physical Sciences) coincided in many respects with a similar calculation suggested by Tsander back in 1924.

From its first days the new Soviet republic began to look far ahead into the future. In 1920 Lenin attended a lecture by Tsander on space flight.

"Would you fly first?" he asked, and when Tsander answered in the affirmative warmly shook his hand.

But Tsander did not live to see the first space flights.

GROUP FOR STUDYING REACTION PROPULSION (ГИРД)

The first such group was organized early in the 1920s in Moscow. Its members gathered in a damp basement room in an old Moscow building. Among them were Friedrich Tsander, such well-known engineers as B. S. Stechkin and V. P. Vetchinkin and other starry-eyed dreamers, old and young. They designed rockets and tested models, rejoiced at successes, were disappointed with failures, and dreamed of future achievements. They corresponded with colleagues in Leningrad and devoured books sent by Tsiolkovsky from Kaluga.

Outer space was hardly the problem of the day. It was more than a quarter of a century before the sputnik era, but the rocket enthusiasts did not want to wait. They designed and built their ГИРД-X liquid propellant rocket. Engineers L. K. Korneyev and A. I. Polyarny experimented with metallic propellants.

Some parts of the motor could only be soldered with silver. They had no money, of course, but each contributed a silver spoon or cross or cup or something else from home.

"It is extremely hard to work," Korneyev once wrote to Tsiolkovsky. "Sometimes it is all we can do to keep from losing heart. But then we remember you and your work and we carry on with renewed energy."

Tsiolkovsky thought very highly of these followers of his. Shortly before his death, in May 1935, he wrote to one of the group:

"The knowledge that you are patiently and perseveringly carrying out your important and very difficult technical work makes me feel better. There is no newer nor more difficult technology in the world than that of reaction propulsion.

"I can say that only my great proletarian land, only my country can support and bring up people capable of leading the new mankind so boldly to joy and happiness."

SIBERIAN TSIOLKOVSKY

A thin little booklet entitled *The Conquest of Interplanetary Space* was published in Novosibirsk in 1927. The foreword says that "it is the most complete study of interplanetary flight to be found in either Russian or foreign literature of the last few years". Yet it contains only 72 pages. The style of writing is concise and to the point.

"The author's interest lies in the results of his investigations," Professor Vetchinkin writes in the foreword, "and he hardly ever shows how he has arrived at the final formulas, the development of which is rarely elementary and requires considerable mental effort."

This was all the more remarkable as the author of the book, Yuri Kondratyuk, was a mechanic without a higher education. In spite of this, "All the investigations were carried out by the author entirely on his own, with the sole premise that a rocket is capable of leaving not only the terrestrial atmosphere but also the limits of the earth's gravitational attraction."

What contributions were made by this man, whom we justly regard as an outstanding scholar of rocketry and astronautics?

Firstly, he suggested that ozone be used as an oxidizer instead of oxygen, as the resulting propellant has a greater heat value. Secondly, he elaborated the methods of using lithium, aluminium and magnesium as solid propellants; this would make it possible to increase the heat of combustion and use combustible tanks. Thirdly, he developed a formula taking into account the effect of the weight of the tanks and propellant on the overall mass of the rocket, and demonstrated that without expendable tanks a rocket would be unable to overcome the earth's gravity. Fourthly, he suggested a winged rocket which would fly in the atmosphere like an aeroplane; he examined in detail the accelerations at which wings would be of use, the optimum trajectories, etc.

Kondratyuk was not only a scientist dealing in highly specialized problems. He was also a thinker who realized the tremendous vistas that could be thrown open to mankind by interplanetary travel. "It will no doubt prove feasible," he wrote, "for mankind to master resources that will enable him to improve radically the conditions of life on earth, by carrying out land improvement on a vast scale and, in the not too distant future, by attempting such ambitious projects as changing the climate of whole continents."

Kondratyuk's book is a direct appeal for early practical steps towards space flight. He even offers an estimate of the possible cost of such a project. As he writes, "The very probability of mastering our own planet in the near future is an indication of the great importance of subsequent conquest of the expanses of the solar system."

He was killed in action in 1942. Although he was not destined to see his dream come true, he firmly believed that it was not just an empty dream. Fifteen years after his death the world's first artificial satellite went aloft. Among those who paved the way for that triumph of Soviet science and technology was Yuri Kondratyuk, the "Siberian Tsiolkovsky".

HITTING THE BULL'S EYE

The ballista was the original ancestor of modern artillery. At school we were taught that the motion of a stone thrown at an angle to the horizon is opposed by two forces, the earth's gravity and the resistance of the air, the resultant path being a parabola. The resistance of the atmosphere is such that a three-inch shell which would otherwise have travelled 20 kilometres falls only four or seven kilometres away from the gun that shot it. During World War I the Germans built their long-range howitzer, Big Bertha. Its range was greatly increased by shooting the shell into the stratosphere, thus reducing the atmospheric drag.

When the first ballistic missiles were being built their designers knew that they needed to lift the missiles beyond the atmosphere and only then accelerate them in the required direction. In the rarefied atmosphere at the fringes of outer space the principal force acting on a missile is the gravitational attraction of the earth.

When a missile reaches the upper atmosphere its rudders turn it at a certain angle to the horizon and it is accelerated along its course. For a given acceleration the range of a missile depends on the angle at which it is shot. The optimum angle of elevation, as it is called, is that which carries a missile the greatest distance. For short-range missiles it is 45°.

Sometimes the missile men are interested in a complementary problem, namely, the angle of elevation at which a missile can be delivered to a set target with the least expenditure of propellant.

Over long ranges the optimum angle of elevation is small and maintaining it is tricky as the angle of approach to the target is also very small. This means that a small deviation can take it wide off the mark. Rocket tests carried out by Soviet missile men hit the bull's eye over a range of 12,000 kilometres.

HIGH-ALTITUDE SOUNDING

When balloons were the only vehicles that could be used for sounding the upper atmosphere the upper limit for direct observations lay a mere 30 kilometres from the ground. Much of the data about the regions above that altitude was obtained by indirect methods which, naturally, carried a large measure of error, The advent of missiles caused a revolution in meteorology, geophysics and other sciences. One of the first Soviet geophysical rockets, launched shortly after the last war, attained an altitude of 80 kilometres. The nose container separated from the carrier rocket and dropped to earth on a parachute. As the descent was comparatively slow the instruments could record much important data.

Today geophysical rockets can climb several hundred kilometres up into the outer layers of the atmosphere and bring back a wealth of information. They have found, for example, that the temperature does not fall steadily with altitude. At 10,000-14,000 metres above the earth the temperature is 50-55 degrees Celsius below zero. Around 45 kilometres up it is warmer, and the thermometer shows 15°C above zero. The temperature then falls again to minus 70°C at 80,000 metres.

Geiger counters mounted in geophysical rockets have helped scientists to establish that the polar lights are caused by charged particles. Geophysical rockets discovered the X-radiation of the sun. They were invaluable in the comprehensive research programmes carried out during the International Geophysical Year.

TWINS IN SPACE

Nature, like a considerate mother, has wrapped the earth in envelopes of air, (the atmosphere), electricity (the ionosphere) and radiation (the Van Allen belts). The radiation belts are densely populated with charged particles that bombard every body entering their domains. Many of them have energies so great that they can penetrate inside a space ship. Obviously, when we send up an astronaut we must be sure that he will return safely to earth and, in particular, that he is protected against radiation. We must therefore know accurately the hazards that may await him in the neighbourhood of the earth.

Radiation also presents a danger to some of the materials that go into the manufacture of rockets and space ships. It may cause the glass of optical systems and portholes to grow dim.

Powerful bursts of radiation may put the solar batteries out of order. This, incidentally, happened with an American satellite following a high-altitude nuclear test carried out by the United States in 1962.

It was to study these and other hazards of circumterrestrial space that the Soviet Union launched the twin satellites, Electron-1 and Electron-2, on January 30, 1964. They were put into orbit simultaneously by one rocket. Electron-1 has an apogee of 7,000 kilometres, and its task is to study the inner radiation belt and the inner fringes of the outer belt. Electron-2 passes through the outer radiation belt and soars beyond it 68,000 km into space, where gravitational and magnetic fields and cosmic radiation reign supreme.

The identical instrumentation of both Electrons enables the scientists to draw a picture of the spatial distribution of the radiation belts and to link together the various data for different points in space.

The upper atmosphere and the radiation belts display seasonal changes. These are being studied with a second pair of Electron satellites launched on July 11, 1964.

MANOEUVRING IN SPACE

The first manoeuvrable Soviet space vehicle was the Polyot (which means "flight"), launched on November 1, 1963. It was unmanned, being operated from the ground, but its manoeuvres in space provided important information for future space flight. The establishment of permanent satellite stations orbiting the globe, and flight to the more distant planets of the solar system will require rendezvous between space ships in space. The Polyot launching was a step towards this goal.

There are two aspects to the problem: rendezvous and docking.

By rendezvous we mean that a spacecraft launched from earth will locate and approach another vehicle already in orbit.

By docking we mean that the two vehicles will come together to transmit men and materials from the ferry space ship to the orbiting station or giant vehicle that must be built for distant space travel. Both tasks are far from simple, and will require much preparation and many tests.

If the orbiting vehicle is comparable in size to the ferry spacecraft, the latter must dock very carefully as otherwise it could knock the satellite out of its established orbit.

When the ferry vehicle closes in to the satellite it will nose up carefully to the docking collar where mechanical latching fingers will snap the two craft vehicles together. The astronauts will then pass through a hatch from one vehicle to the other, transfer the cargo, and the ferry space ship will return to earth for another cargo.

STEPS INTO SPACE

If men ever land on an asteroid, Hermes, for example, they will have to move very carefully; an uncalculated leap would carry a man away from the surface and into outer space. The escape velocity of Hermes is only 70 centimetres per second. On earth an object must be accelerated to almost 7.9 kilometres per second to place it in a satellite orbit in which it circles the globe once every 90 minutes.

The next step into space is the escape velocity, the speed needed to escape the gravitational pull of the earth, which is 11.2 kilometres a second. But a rocket launched with this speed remains a captive of the sun, as did Luna-2, which in January 1959 became the first man-made planetoid to revolve around the sun. To escape from the sun forever a velocity of 16.6 kilometres per second is required (in the direction of the earth's motion in its orbit).

In other words, future spacecraft will have to have three speeds: orbital—7.9, planetary—11.2, and stellar—16.6 kilometres per second.

LADDERS INTO SPACE

A messanger gallops along a road, dust rising in his wake and his horse dripping with lather, yet he urges it on and on with his spurs. His mount collapses, he hurriedly changes over to a fresh horse and continues his journey.

The rocket stands like a silvery column propping up the sky. Way up on top nestles the spacecraft which it is to launch on its way to other worlds.

Five, four, three, two, one. Fire!

The rocket balances itself for a few moments on a fiery tail and then hurtles upwards. Faster and faster, higher and higher. It puts the whole might of its motors, and the whole energy of its propellant into this terrific upward lunge. But when the propellant burns out the rocket turns into a dead weight pulling the vehicle back down to earth. At this moment the couplings release the first stage and it falls to earth. The second-stage motors go into operation, then the third, until the final stage accelerates the satellite and follows it into its orbit. Nowadays the jettisoned stages burn up uselessly in the atmosphere or crash to earth. In the future the launching stages of spacecraft will be provided with wings so that they can glide safely back to earth and be re-used many times.

All of the mighty modern rockets are multistage installations. The simplest type is two stages in tandem. Similarly, three, four or more stages can be arranged in tandem. Another method is to fix the initial stages round the body of the last stage. Or they may be arranged symmetrically on two sides of the last stage. Various combinations of these designs are also used, for example, the third and second stages in tandem with twin motors of the first stage on both sides of the second. In some rockets motorless stages are installed; these are actually jettisonable tanks which are cast off as they empty. Space rockets are like ladders up whose rungs the spacecraft climbs towards its destination.

WHILE THE MOTORS ROAR

Slowly, apparently unwillingly, the rocket rises from the ground. It accelerates faster and faster, and in a few seconds disappears from sight. It passes through the dense layers of the atmosphere where the resistance is so great. Great quantities of propellant are used in overcoming the first few dozen miles.

The rocket passes beyond the stratosphere and into the ionosphere, racing on and on to achieve the escape velocity that will free it from the bonds of the earth's gravitation. At last the spacecraft breaks away and travels on through the boundless void towards its goal.

If the motor had to work all the time it would consume millions of tons of propellant.

It is impossible to build a rocket big enough to carry that much propellant. Can it reach its goal with the available propellant stocks? The answer is yes. Nature comes to the rescue.

A carriage comes to a halt as soon as the horse stops. Stop the engine and a vehicle rolls to a halt. But a rocket doesn't slow down when its motors are switched off. This is not only because of the tremendous speed at which it is travelling. Its flight is sustained by the gravitational attraction of the sun. A spacecraft that has attained the escape velocity becomes a satellite of the sun and, if suitably directed, can reach Mars, Venus or any other planet without resorting to its motors—just as an artificial satellite accelerated to the orbiting velocity coasts round and round the globe.

That part of the initial trajectory during which the motors function is called the boost stage. When the motors are cut out coasting or free flight begins. The boost stage is the worst, as far as the astronaut is concerned, for that is when he must bear the full force of the acceleration, or G-loads. Here is how Gherman Titov describes his sensations: "A thunderous roar filled the cabin, the rocket began to vibrate and a tremendous weight bore down upon me. The G-load increased, and I thought what a good thing it was that we cosmonauts had trained a lot on centrifuges and vibration stands so that we got used to the sensations of space flight."

During the boost stage it is very hard for the astronaut to control the rocket, and this is done by instruments. They must function with a tremendous degree of precision. The slightest fault can jeopardize the success of a launching and the very lives of the crew. In launching a rocket towards the moon a deviation in the flight direction of only one quarter of an angular degree will take the rocket 8,500 kilometres off the target, which is two and a half lunar diameters.

During the coasting part of the flight the G-loads are replaced by weightlessness and the astronaut can move about and work. If the need arises to change the direction of flight he switches on the motors and the acceleration loads come into play again.

SWEATING ROCKETS

It was sweltering down on earth but the pilot was cold. Cold crept through his thick padded suit, and even the heating in the cabin was of no avail. Only the electric current passing through wires woven into the lining of his suit made it comfortable enough for him to think and work.

Malcolm Scott Carpenter found that the thermal insulation of his spacecraft was imperfect. The heat generated by its motion through the rarefied atmosphere seeped inside. The temperature rose to 40 degrees Celsius and more. It was hard to breathe. Only his presence of mind and courage enabled him to complete his flight unharmed.

Gherman Titov saw the shell of his Vostok-2 spacecraft glow with all the colours of the rainbow as it streaked through the air. But inside it was room temperature, 22 degrees Celsius. "I knew that nothing would happen," he said later. "The spacecraft's heat insulation had been tested many times and it is completely reliable."

So one can be quite comfortable up there.

Heat insulation. On hot days people in Central Asia wear thick padded robes and fur hats. The temperature under the robe is the body temperature 36.6°C, and the robe acts as a shield from the scorching 50, 60 or 70 degrees of the sun.

Aicraft, too, are coated with protective coverings to prevent overheating. A titanium alloy coating withstands heating to 370°C (at up to 3,600 kilometres an hour). An aluminium hull would lose 4/5ths of its strength at that temperature.

Today materials combining the best properties of ceramics and metals have come to replace titanium and beryllium as protective coatings for aircraft.

For spacecraft, however, they, too, are insufficient, and various additional coatings and ingenious devices are made to protect them from excessive heat.

A suitable protective coating is a many-layered ceramic shell which melts and burns up as the vehicle enters the dense layers of the atmosphere.

Another kind of thermal shield is a porous metal-ceramic hull that "sweats"; water is exuded through the pores, evaporates and carries off heat, just as sweat cools the skin on a hot day.

ROCKET FUELS

First there was wood. And the dancing flames of primative man's fires. And the comforting warmth of the kitchen hearth. And the first efforts of the steam boiler.

Then there was coal. And miniature suns entered houses in bulbs of glass. And railways covered the earth in a network of steel.

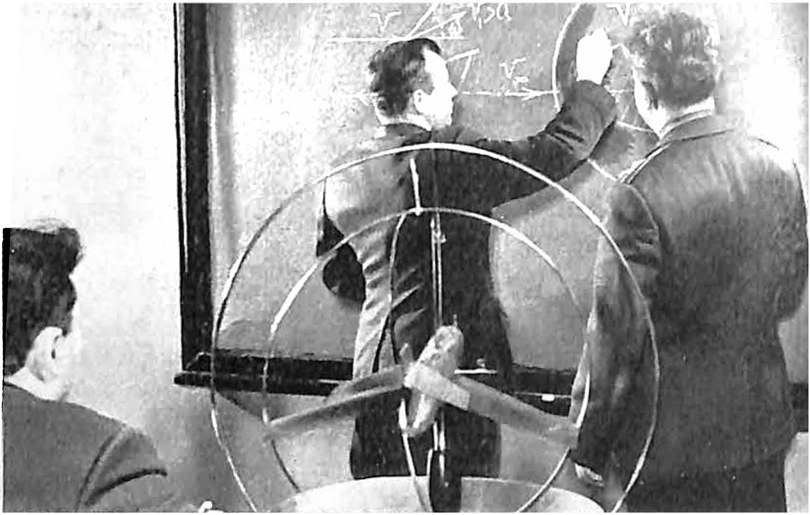
There was also oil. With it came the internal combustion engine and the jet engine. And vehicles that devoured kilometres and aircraft that reduced distances.

Energy stored away in fossil fuels and liberated by man brought him independence and power over the forces of Nature. Fuel helped man to transform the earth and conquer space and time. But only on earth. Only at home. No further than the threshold of the earth's gravity.

Yet people's eyes were turned outwards, to other worlds, to the unknown. Dreams were born. They drove men, but they could not drive rockets. A new kind of fuel was needed. It had to be powerful enough to overcome the earth's gravity, have a high energy content to keep the weight of the rocket down, and have a high density so that more could be stored away in the fuel tanks.

Dreams drove people on. Scientists turned them into reality in the laboratories. They calculated and tested thousands of variants. Gradually the field of search narrowed, until only four groups of fuels remained: fuels that yield energy on oxidation; endothermic substances

Preparation for a flight begins in pressure chambers, catapults, centrifuges. . . .



A knowledge of theory is indispensable in flight

In a weightlessness basin. In space, this state continues for weeks on end

that yield energy by splitting into elements or groups of atoms; free radicals, which are chemically active "fragments" of molecules; and, finally, nuclear and ion fuels.

The first group is the largest and the oldest. Chemistry has perfected it in many ways, but the essence remains the same. Conventional fuels burning on earth are oxidized by the oxygen of the atmosphere. But a rocket flying in outer space cannot count on free oxidation, and some of the rocket's tanks must be filled with special chemical substances called oxidizers.

There are tried and tested oxidizers, such as oxygen compressed into a small volume. There is also nitric acid, which compares favourably with other oxidizers, and can be stored for long periods combined with nitrogen tetroxide without deteriorating. It is therefore useful in missiles, such as anti-aircraft missiles, that must be kept in readiness for launching.

Some substances are being used as oxidizers for the first time. Ozone is better than oxygen as it has one more oxygen atom. Fluorine is the most powerful oxidizer. Second comes chlorine trifluoride, which is so active that even glass-fibre cotton, which is conventionally used as a fire-proof material, burns in it. Then there is hydrogen peroxide, the haemostatic and disinfectant used in household first-aid kits. It was used by the Germans during World War 2 in the Messerschmidt-163 interceptor fighter.

There have also been new developments in the fuels to be oxidized. In addition to kerosene and alcohol, which the Germans used in their V-2 rockets, and liquid hydrogen, which has the highest heat value of them all but which is much too dangerously explosive, new classes of chemical compounds are being used as rocket fuels. Here are some of them.

Dimethyl hydrazine, in which two atoms of hydrogen are replaced by two methyl groups. Hydrazine hydrate, hydrogen peroxide's neighbour in the Messerschmidt-163. Boranes, which are hydrids of boron, the element with the third greatest heat content. And finally, strange though it may seem, come metals, or rather suspensions of powdered metals, preferably magnesium, in hydrocarbons such as kerosene. These fuels require modest quantities of oxidizer, only one-fourth or one-fifth of that required for the combustion of pure kerosene.

The future of rocketry depends on the last three groups. There can be no doubt that the physicists and chemists will have them ready in time for man's more ambitious flights into outer space.

ROCKETS TRAVEL ON THEIR OWN

Babies must be led by the hand. They can't walk yet and stumble and trip at every step. When a child gets tired solicitous parents take him in their arms. Children are fortunate; they are taught how to live and prepared be for the difficulties of life.

Man is just as solicitous about the creations of his hands. People operate lathes and man ships and vehicles. Yet how much simpler it would be if steel were produced, lathes operated and railway trains driven without the participation of man.

But this is only a dream, and even aeroplanes must still be guided by hand.

Rockets are another matter. They are hurled up into the blue and travel away into the depths of outer space without being guided by the hand of man. They are led on by radio signals. Other operations, like steering the right course, turning and jettisoning the rocket stages, are carried out by the rocket itself. In place of their hands the designers have substituted automatic instruments which carry out these complex manoeuvres.

A rocket rises up from its launching pad and begins to climb vertically in order to pass through the dense layers of the atmosphere as quickly as possible. The motors are working at full capacity. But a treacherous wind tries to turn the rocket from its vertical course. Its effects are countered by an artificial horizon gyroscope which maintains the position of its axle unchanged regardless of changes in the rocket's attitude. The result is that electrical contacts are closed, switching on servomechanisms that actuate the jet rudders and restore the rocket's attitude.

Another duty of the artificial horizon gyroscope is that of turning the rocket in the required direction after it has passed through the dense layers of the atmosphere. A programme mechanism alters the position of the axle of the gyroscope so that there is an "imaginary" displacement of the rocket from its course, the contacts close, and the rocket turns until it occupies the position specified by the flight programme. The automatic device sees to it that the rocket "behaves itself" and doesn't roll, yaw or pitch.

When the rocket acquires the required inclination to the horizon it must have a specific velocity, which means that the motors must be switched on for a specific period of time. This is effected by so-called integrators, which may be electrolytic, for example. In an electrolytic integrator current is made to pass through a solution of, say, silver chloride. The current passing through the electrolyte is proportional to the deflection of a common pendulum, which in turn is proportional to the rocket's acceleration. Thus, the quantity of silver chloride transported through the electrolyte is proportional to the rocket's velocity.

When all the silver has been transferred to one electrode this is a signal that the required velocity has been achieved. Simultaneously the rocket is inclined at the required angle to the horizon. These two signals trigger the switching on of the motor of a new stage and the jettisoning of a burnt-out stage, or of the payload in the rocket head—placing a new artificial earth satellite in the sky.

Automation is all very well, of course, but the designers would like to see in place of electromechanical devices a compact radio effector unit which would carry out all operations on commands from the earth. The ultimate dream is to produce automatons capable of developing and carrying out their own programmes as the flight proceeds.

★ IV ★

The turbines will roar,
Whisking me into the bottomless void.
With me there will be
All the great wisdom of men.
The warmth of their hearts,
And their strength will be with me.

ROBERT ROZHDESTVENSKY

HERE WE GO!

Yuri Gagarin is a lucky man in more ways than one. To begin with, he was born a citizen of the Soviet Union in 1934, just in time, as it later turned out, to be the first man in outer space. He proved to be a healthy young man of just the right height, weight, age, and whatever else was needed to qualify for the job. He was a fighter pilot, from whom the first candidates for space flight were recruited.

His road to the Baikonur cosmodrome began in the Gzhatsk District, Smolensk Region, U.S.S.R. Later he attended a foundry-workers' school, and then a technical school in Saratov, on the Volga, at which time he joined an aviation club. In 1957, he finished an Air Force school in Orenburg, in the south-western foothills of the Ural Mountains. Wherever he studied he was a model student. In 1960 he joined the Communist Party of the Soviet Union. And that was all there was in his life "before".

Most people find it difficult to pindown a turning point in their lives. Some have never had one. A few can boast two of equal importance. One such man was Auguste Piccard, who first built a balloon and set an altitude record and later, in the nineteen-fifties, built a bathyscaphe which beat all the submarine depth records.

The turning point in Gagarin's life is known to all. On April 12, 1961, the world's first manned space ship, Vostok-1, took off from its launching pad at Baikonur and went into orbit around the earth. Radio stations throughout the world reported the facts: weight of the space ship 4,725 kilograms, inclination of orbit to the equator 65°04′, period of rotation around the earth 89.1 minutes, all is going well and the cosmonaut feels fine.

The breathtaking flight lasted 108 minutes. But what minutes they were! Behind each of them lay centuries of struggle, labour and search, and the persevering work of thousands of the best minds on earth. Man's dream of flying carpets, the works of Leonardo da Vinci, the martyrdom of Giordano Bruno, the laws of Newton and Einstein, the Montgolfier brothers' balloon, the world's first heavier-than-air aircraft of Mozhaisky, the works of Tsiolkovsky, the exploits of the Soviet wonder pilot Chkalov, the concerted effort of a nation that produced wonder rockets and wonder vehicles, and finally a new stage in the unravelling of the mysteries of Nature.

It began with a joke. When the command was given to start the engines, Gagarin exclaimed happily, "Well, here we go!" We can imagine how he enjoyed the realization that the grind of preparatory work was over; all those tests on centrifuges, vibration stands, sealed cabin simulators, high-altitude chambers and all the other paraphernalia of cosmonaut training. It seems that fifty parachute jumps were by no means the worst experience. In short, to gain an idea of what the training of an astronaut involves you will have to look through most of this book.

But Gagarin did not complain. The specialists even say that he enjoyed the grind. In any case, he was more than rewarded for his pains when he became the first man to see what the earth looks like from outside. And though, as he said later, it defies description, he did try to give us an idea. His very first impression was: "A wonderful sight!"

Seas, mountain ranges, rivers, forests and big cities could be seen from above. In daylight the earth appeared to have a bluish halo that blended gradually into violet and black. The sun was much brighter and the stars stood out against the black background of the cosmic void in stark relief. As the sun rises it shines through the atmosphere and the earth's halo displays all the colours of the rainbow, from a golden yellow, through to pale blue, blue, violet, and black. Certainly a wonderful sight, and let us hope that we too will one day be able to see it.

Besides observing the earth from outside there were other tasks with a direct bearing on man's conquest of outer space. They stemmed from the two main features peculiar to space flight; weightlessness and acceleration, or G-loading. What are their effects on the human organism? The pertinent data as represented by cardiograms, the measurement of blood pressure, respiration and other bodily reactions were transmitted to earth via the space ship's telemetering system. These were supplemented by Gagarin's own testimony: "Good flying."

In science, especially at crucial junctures, the need arises to test the results of scientific experiments on man, for in the last analysis science works for man. There was the first man to test the effectiveness of smallpox vaccination, the first man to go under water in a diving suit, and the first man to fly in the air. The first is always a hero. It is a great honour to be the first, but it is also dangerous, for in spite of all precautions the first can never be quite sure that everything will come off without a hitch. Yet it must be done, for everyone else's sake, and the thoughts, hopes and love of the men and women of the earth go out to the first. Gagarin was fortunate. He was the first. The first of a type never known before on earth, and the welcome accorded him befitted his exploit. Gagarin received his first token present on board the aircraft that picked him up when he landed. It was a plastic globe with a space ship circling it. The whole world lay at his feet. The plane did a circle of honour round the capital, and crowds turned out to greet him in Moscow, London, Tokyo and many other capitals of the world.

Yuri Gagarin has become a symbol of the courage, perseverance and boundless possibilities of man. His name belongs in history.

But perhaps he doesn't want to be a historical personage and a symbol? After all, it is rather discouraging to have everybody think that you have already performed your greatest exploit. Cosmonaut-1 makes no secret of his thoughts on this score.

"I want to visit Venus and see what lies hidden beneath its clouds, and I want to visit Mars and see for myself whether it has canals," he said after his trail-blazing flight.

Good flying, Yuri Gagarin!

A DAY IN ORBIT

Gherman Titov is known to the world as Cosmonaut-2. He is the second man to have experienced the exhilaration of outer space, to have endured G-loads and weightlessness, and to have seen our eternally spinning globe from the outside. Furthermore, he has shared some of his experiences with us by bringing back motion picture films of the earth from an altitude of more than 200 kilometres.

Undoubtedly Titov is Cosmonaut-2, but there is a certain injustice in the term. To be sure, he followed Gagarin, but he is not as "second" as all that. Together with Gagarin he mastered the Vostok-1 space ship, together with Gagarin he prepared for the first manned flight, and had the need arisen he would have coped with it as successfully. Only after Gagarin's report, "Ready for blast-off" did Titov get out of his space suit and become a mere observer.

And then he began to prepare for a much more difficult flight. In other words, Titov can with every right be said to have taken part in both the first and second space flights.

The whole of Titov's adult life was subordinated to one dream: flight. In 1953 he finished school in the village of Nalobikha, in the Altai Territory, in south-western Siberia. He matriculated with excellent marks in all subjects except geography and astronomy, but this did not prevent him from entering an aviation school. He graduated with honours. "A brave and efficient flier," says his testimonial. In 1957 Titov graduated from an Air Force school at Volgograd, and as Lieutenant Titov became a fighter pilot.

Besides being a specialist in his trade, Titov is an excellent gymnast, cyclist and acrobat and an invariable participant in amateur art activities. He likes art and is a great lover of poetry and belles-lettres. On the eve of his flight he laid a bouquet of fresh flowers at the foot of a statue to Alexander Pushkin, his favourite poet. Love for poetry is a family tradition with Titov, and he even owes his name to the hero of Pushkin's *Queen of Spades*.

Titov became a cosmonaut in 1959. He had two years of training and studies, and by April 1961 he was ready for the first flight into outer space. Finally, in August, Major Gherman Titov, cosmonaut and Soviet citizen, went into orbit around the earth on board the Vostok-2 space ship. His task was to investigate the effects of prolonged space flight on man, and his working ability in a prolonged state of weightlessness. He proved that man was up to the task. Moreover, Titov twice assumed manual control of his vehicle. Oceans and continents floated past the portholes, and Titov found that each was characterized by a specific colour. He recorded his impressions in the flight log, took cine pictures, ate and slept. His flight lasted more than a day. Its results paved the way for Nikolayev and Popovich.

In 25 hours 18 minutes Vostok-2 circled the globe more than 17 times, travelling over 700,000 kilometres. Night followed day thirty-four times. Finally the whole world heaved a great sigh of relief the flight was over. Swaying beneath the canopy of a red-and-white parachute, Titov landed in the same region as Gagarin had four months earlier. His friends were already there waiting for him.

COOL AS A CUCUMBER

To begin with, when Andrian Nikolayev was a boy, his surname was Grigoryev.... This, of course, was because until fairly recently Chuvash tradition required a boy's surname to be derived from his father's first name.

Correspondents who mobbed Gagarin wondered: "Where did this combination of aristocratic family name, working-class background and radiant smile come from?"

Nikolayev is of peasant stock. And his smile is different. And he has a very common family name, though some people abroad found a way of contracting it to "Niko". His life, too, was simple and ordinary, with no great incidents. But then, that might be the most remarkable thing in it. He was born on September 5, 1929, in the village of Shorshely in the Mariinsko-Posadsky District, Chuvash Autonomous Republic. As a boy he tended cows and tilled the fields of the Pobeda collective farm. There he read his first books and came to love the heroes of Chuvash legends, the peasant leader Pugachov and the Red commander Chapayev. There he dreamed of the future.

"I'm going to be a doctor," the adolescent declared. "I'm going to be a flier," the young man decided.

He graduated from a forestry school in 1947 and went to work in Karelia, in the north-west of the Soviet Union. There he learned to feel the beauty of the earth, to admire the colours of the forest and to listen to the magic silence of backwoods lakes. He did not yet think of the beauties of the sky.

Then, in April 1950, Nikolayev was called up into the army. His first acquaintance with aircraft came when he became a gunner-radio-operator. He finished an Air Force school and served in the Moscow Military District, flying Yak and Mig aircraft. "A good fighter pilot with a clear head," was the testimony of Hero of the Soviet Union A. L. Kozhevnikov. Soon Nikolayev had an opportunity to show his worth.

In the summer of 1956, at an altitude of 6,000 metres, the engine of his aircraft suddenly stopped dead. The instrument dials—it was better not to look at them even. He reported to ground control, but they took a long time replying. The obvious thing was to bail out. But then the plane would be destroyed, and with it the work of hundreds of people. He clutched the joystick and landed the plane on its belly in a field of rye, the only suitable landing strip, hemmed in by a gully and a hillside.

"How did you do it?" his friends asked him.

"I kept cool," he said.

The disposition of this stocky, dark-haired young man was moulded by the routine of army life. Taciturn, neat, smart in appearance, and punctual. And with remarkable coolness and grit.

He remained true to himself in the silence of the sealed cabin simulator, where he spent many days completely isolated from the outside world. He calmly took his seat and calmly made notes in the log. After a week of total silence the light suddenly went off, a crimson beam flickered in the darkness and a siren wailed. Hardly batting an eyelid, Nikolayev watched the performance to the end, smiled to himself when it was over and resumed his task as if nothing had happened. The doctor could only spread his hands in amazement: "Nerves of steel."

Nikolayev remained true to himself in the "heat chamber", where he was all but roasted alive. He trained for hours on end on a swing until he could stand it for 24 hours. Later members of the commission that examined him before his flight were amazed at the ease with which he maintained his bearings, equilibrium and coordination of movement. When, on the eve of his flight, a fuse blew during a game of billiards his cue didn't waver and he calmly pocketed the ball.

In outer space, when the space ship entered the atmosphere in a ball of flame he said to himself: "Easy, this is a normal re-entry."

"Remarkably calm, unhurried and modest, capable of taking independent decisions, he reminds one of Aleksei Maresyev*. Many of us cosmonauts took a liking to this good-humoured, clever, strong-willed person who can take rapid decisions and think boldly and lucidly. One can work eternally with such a man." This is the testimony of Gherman Titov, whose stand-by partner Nikolayev was.

In April 1961, Nikolayev witnessed Gagarin's take-off. Four months later he came to the launching site with Titov, wearing a brightly coloured space suit. He knew that the next turn was his.

On August 11, 1962, at 11.30 a.m. Nikolayev took off on board Vostok-3. His assignment was for a long spell in outer space, and he had many tasks to perform. He had to study the effects of prolonged weightlessness, check his working ability when floating freely in space and check the operation of all systems and mechanisms in flight. He had to be a veritable Jack of all trades.

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* Aleksei Maresyev, a fighter-pilot, was shot down over German-occupied territory during the last war. With both legs broken, he crawled for two weeks over the snow-covered ground to reach his own positions. As a result of his experiences he had both feet amputated, but he nevertheless learned to fly a fighter plane again. Maresyev took part in many missions and major air battles and shot down several enemy planes. He was awarded the title of Hero of the Soviet Union. His exploit was described by Boris Polevoy in the novel *A Story of a Real Man.—Ed.*

In 94 hours 22 minutes he circled the earth 64 times, travelling 2,640,000 kilometres, and carrying out his entire programme perfectly.

He was the first to establish radio communication with another spacecraft, the Vostok-4, piloted by Pavel Popovich. He left his seat in the cabin and experienced the sensations of being freely suspended in space.

For the first time a cosmonaut's rations included conventional food. Until then there was no way of knowing if a man could chew and swallow in weightless conditions. Nikolayev's menu included cutlets, roasted veal, chicken fillet, rolls, sandwiches, fruit, cakes and sweets. He had water, coffee and fruit juices to drink.

Probably his one regret was that he was unable to attend the Soviet soccer cup finals, but he did send his congratulations to the winners from aloft.

What did he think of up there?

That the earth had become quite small if you could fly round it in 90 minutes.

That his flight was merely a reconnaissance operation, a small step towards future flight to other planets.

That the time spent in outer space, where the moon is so bright that he could switch off the light in the cabin, was a thrilling experience.

And that, cut off though he was from the world, he felt the presence of millions of Soviet people whose efforts had carried him so high up. As he wrote later, "the best support is the sense of responsibility to our country and our Communist Party."

"After four days of flight I became good friends with outer space. Now I see things in an entirely different light from before. The stars no longer seem cold and distant, but on the contrary appear as warm and friendly luminaries. The earth has become a hundred times better and dearer, and the moon looks like an old friend. Outer space has come closer, and I feel that I can face it on equal terms."

WORRIES ON EARTH

After the stirring send-off given to Andrian Nikolayev and the hectic day that followed, Pavel Popovich retired to his quarters for a last night's sleep before taking off himself. The little building where cosmonauts spend the last night before a flight stands in a cosy nook, surrounded by leafy poplars. When Popovich entered he saw the pictures of three cosmonauts on the wall. Two of them were there to wish him good night; the third was in orbit.

Next morning he ate an ordinary breakfast and dressed up for his flight. He wore a brightly coloured space suit with a small mirror strapped to the right sleeve for cheerful, song-loving Pavel to take a look at himself during the flight. At the cosmodrome he bid farewell to those remain-ing behind and entered the cabin of his rocket. Up he went in a roar of flames and the bright stab of light disappeared into the billowing clouds. Almost at once he heard Nikolayev calling him, and then Vostok-3 appeared in sight. "All goes well, Andrian," Popovich told his friend.

Popovich merrily laughed, talked, and sang songs. Glowing sparks—products of combustion—flitted by, and oceans and continents dropped behind the horizon. The flight of 48 circuits of the earth began. "There was god, a stone's throw away. I asked his name and he said, 'Nikolayev, Andrian.'" Later on, in the television studio, they watched themselves on film and described the flight. At the beginning of the broadcast Popovich commented: "I'm not used to facing such a large audience. I'm more excited than before the flight."

Space flight means G-loads and weightlessness. Their effects are still not known for sure. Popovich likes solving problems, and in fact, mathematics was his favourite subject. He had plenty of problems to solve in flight. After his return he declared that weightlessness remained a mystery. It is hard to say what one can expect from it, pleasure or pain. Be that as it may, the experiments were successful. They were extremely interesting, for the very fact of men experimenting in outer space introduced a new dimension into scientific research.

Popovich's first impression when he felt himself floating in mid-air without support was that he had turned upside down in his space harness. It did not matter whether the earth appeared overhead, below or to one side. He could orientate himself only within the space ship, and only when he had his eyes open. It was a pity there wasn't a barbell weighing several hundred kilograms so that he could break all the weight-lifting records. But he had things weighing a few pounds and he could demonstrate to television viewers (who at last could get a glimpse of outer space right in their homes) some of the freaks of weightlessness. He spent an hour every day floating freely while telemetric instruments recorded his body's reactions to the strange state.

Popovich had to carry out tasks designed to check his ability to work, his nervous and psychic reactions and his sense of time. He had to choose geometrical figures in a given order, make arithmetical calculations with big numbers and record his sensations.

His notes were compared with notes made after similar experiments in the same cabin on earth. The effect of weightlessness on oxygen consumption and carbon dioxide output, and even its influence on taste sensations and appetite were determined. Popovich reported an excellent appetite, and slept soundly without dreams.

The purpose of all this is clear. During Nikolayev's and Popovich's flights much was done to prepare for the eventual leap to other worlds. There were many firsts. For the first time communication was established between two space ships, which were for the first time in flight together, coming as close to one another as 6.5 kilometres.

Pavel Popovich's flight, which began on August 12, 1962, lasted 70 hours and 57 minutes. He broke no records, but he helped impress on human minds the idea that space flight was becoming common. From an isolated exploit it is turning into a conventional means of space research.

THE STARS COME CLOSER

"What lifts man up and leads him forward?"

"His dreams," was Valery Bykovsky's reply to journalists before his flight.

Dreams had lured him on all his life. He was born in 1934 in the town of Pavlovsky Posad, not far from Moscow, and as a boy dreamed of becoming a sailor and devoured books about adventures and exploits. Later he shifted his allegiance to the sky, where the latest machines were blazing the trail into the future. Airmen scored victory after victory over the elements. Valery was impressed most by the flight of the pilot Anokhin, the first Russian to break through the sound barrier. His future was clear. He mastered the ABC of aviation in an aeroclub, and later graduated from an Air Force school and became a fighter pilot. The ingenious Valery was a crack pilot, merry and witty, but nevertheless he was not content with what he had achieved and continued to study intensively on earth and in the sky. What else could he think of?

Energy, a determination to face up to difficulties, and a desire to bring one's internal powers into play frequently lead to an urge to perform a feat of some kind, to rise above the average level and prove to oneself one's ability to be out of the ordinary. Was it this urge that induced Valery Chkalov to perform his famous, and at the time scandalous, feat of flying his plane under a bridge span? The young namesake of the celebrated pilot found an outlet for his energy in driving a motorcycle at top speed, without even a driver's licence. As often as not both bike and rider suffered injuries.

He was a daring flier, and delighted his mates on earth with his antics. But the dashing Air Force captain, with his regulation peaked cap cocked over one eye, did not always make a favourable first impression on strangers. The cosmonaut selection committee, at least, were dubious when he presented himself before them. "No good," they decided, "not serious enough." But then, when they asked his commanding officer: "Who is physically the best-trained man in the unit?" The reply was:

"Bykovsky."

"Who is the best flier?"

"Bykovsky. You can see him in action for yourself."

And they saw him in mock air combat, from which Bykovsky brought back pictures of all his opponents on the film of his gun camera. Thus he embarked on the road to the stars.

Resolution, courage, resourcefulness. These qualities come in handy even in the daily routine of the cosmonaut training centre. The scientists decided that without checking the psychological effects of silence on the cosmonauts and training them for it they could not be launched on their missions. So they built a "silence chamber", called in the cosmonauts and asked for a volunteer to try it out. Bykovsky was the first to step forward. This quality of shouldering the most difficult tasks is probably one of the best in a man. Anyone possessing it always makes a good friend and comrade.

So far physical fitness, along with a high standard of professional training, is the decisive factor in determining a person's suitability to be a cosmonaut. There is hardly a sport in which the inhabitants of the cosmonaut centre do not take part. And here, too, Valery is always in the fore. Gymnast, track-and-field sportsman, volleyball player, goalkeeper. People who ought to know say that as a trampoline tumbler he is as good as a circus actor. Hard work brought Bykovsky to the front ranks. He saw Yuri Gagarin off and met him when he came back. He was stand-by cosmonaut for his friend Andrian Nikolayev. He waited patiently for his turn and continued to work. Everything came in handy. His do-it-yourself approach to things helped him to master the intricate instruments of the spacecraft. His athletic prowess enabled him to adapt his body to the rigours of space flight simulated on earth. And he has one more quality, punctuality. They even say that you can check your watch by Valery. He has never been late. And he was not too late to become one of the first cosmonauts.

At 3.00 p.m. on June 14, 1963, Cosmonaut-5 went into orbit around the earth. He circled it eighty-one times, and at the time of writing he holds two world space records: distance—3,326,000 kilometres, and duration—119 hours 54 minutes. He smiled at us on the screens of our T.V. sets as he demonstrated the effects of weightlessness with various objects, and floated about inside the space cabin collecting more and more data for the flights that were to follow. A cosmonaut has his hands full in outer space, and whatever he does is a test of human abilities in a strange environment. So vestibular tests were followed by physiological tests, and after gymnastic exercises came filming of the clouds, stars, moon and horizon. For the first time in outer space he performed exercises with an elastic band.

In spite of so many "firsts", dreams continue to beckon, and in his mind's eye Valery Bykovsky sees himself making the boldest visions of the science-fiction writers come true. As he himself says, "I have fallen in love with outer space and am longing for the time when I will go up there again."

WOMAN IN SPACE

The young girl in the blue track suit was enjoying a long anticipated meal of potatoes, onions and brown bread. Greyish-blue eyes sparkling with delight looked inquisitively about her as if the surrounding world was reveal-ing itself to her for the first time in all its splendour. 'And this was in fact the case, for Valentina Tereshkova was viewing the world through the eyes of a cosmonaut for the first time. She had just parachuted down at the end of the flight which ranked her, too, among the firsts. The world was agog. Newspapers featured items about the flight, the girl, her family and the role of women in family and society. People recalled Joan of Arc, the mathematician Sofia Kovalevskaya, the Civil War heroine machine-gunner Anka, the flier Marina Raskova, the partisan heroine Zoya Kosmodemyanskaya and many others.

American women complained of the U.S. space authorities unwillingness to recruit women astronauts. Many a man had to celebrate Valentina's flight doing household chores while members of the fair sex avidly sought information about the flight of the first woman cosmonaut and discussed the role of women in the history of mankind.

To be sure, while the women were frankly delighted, the men sought to mask their admiration behind deprecatory smiles. But no one challenged the exploit of Cosmonaut-6, the first woman in space.

Who is Valentina Tereshkova? How does she differ from thousands of others? The answer is simple. She is an ordinary Soviet girl and any other girl could have taken her place. Only she was one of the few who have travelled the road leading into the cabin of a space ship.

Valentina was born into a kolkhoz farmer's family in the village of Maslennikovo, in the

Yaroslavl Region. As in the case of many other children of her generation, the war took its toll of her family. She was four years old when her father was killed in action. Her mother had her hands full with three children, but Valentina and her elder sister Lyudmila helped a lot around the house. Only sometimes she would use the scissors to trim the window-plants or cut up her mother's blouse to make a doll. In her dreams Valentina raced across the sky astride the Little Hunchbacked Horse. In real life she climbed the birch tree in the yard and slid down to the ground along the slender branches, risking her neck. At the age of six she learned to swim.

After the war the family moved to Yaroslavl, and there Valentina saw a steam engine for the first time. She immediately decided that she wanted to be an engine driver. Then came school, and she acquired a love for music and books.

Childhood ended and it was time to contribute to the family budget. After finishing the eighth form Valentina went to work at the Krasny Perekop textile mills. The clock at the top of the tall square tower timed her at her work, her studies in the ninth form of the workers' school and the correspondence Light Industry School, and her activities in the amateur arts circle. Soon Valentina was promoted from mill hand to cotton-spinning technologist. This was nothing extraordinary. She was elected secretary of the mill's Komsomol committee. One wonders how she found time for everything. It would seem impossible to visit all the shops, worry about curtains in the workers' hostel, organize country outings and keep a hand on the pulse of the whole mill. And in addition she kept up her interest in music, literature and painting. Yet even that was not enough.

Valentina joined an aeroclub, and on May 21, 1959, she made her first parachute jump. And thus began her conquest of the clouds. There were achievements and failures and comic adventures, like the time when she landed with her parachute among a herd of cows. As her skill developed she gained confidence in her abilities. She attempted more difficult jumps and her nerves became stronger.

The day of April 12, 1961, was a bombshell. Man in space! No one could remain indifferent, but the event seemed to have a direct bearing on Valentina. Her first acquaintance with outer space was at a showing of the documentary film, "First Trip to the Stars". She went to see it several times. Gradually the bold idea formed in her head. Was Yaroslavl any worse than Gzhatsk? And a woman was certainly just as good as a man. Valentina wrote a request to be enrolled at the cosmonaut training centre.

She made her hundredth parachute jump as a member of the cosmonaut training team. She learned to fly an aeroplane and to master space-flight techniques, and went through the same rigorous training as her male colleagues. Still, the question remained: how would a woman endure space flight, how would it affect her organism? Once again there was the difficulty of being the first. Once again the unknown quantity of the end results.

At 12.25 p.m. on June 16, 1963, Yuri Gagarin declared there was five minutes to go before blast off. Five, four, three, two, one. Fire! Cosmonaut-6, the first woman in space, was off. There was the usual routine. Recording observations in the log and on magnetic tape, vestibular and psychological tests, taking pictures. One sleeps well in outer space but one's weightless hands seem to get in the way. She followed Gherman Titov's advice and stuck them under the braces of her seat harness. She woke at 6.10 in the morning and got down to work again. The original programme had been drawn up for a day's flight, to be extended to three days if her condition permitted. This was the case, and the ship continued to wind round and round the globe. Continents and oceans, mountains and valleys passed by the portholes. The Pamir Mountains were red, with white spots which were glaciers, and the Cordilleras were a dark grey. Nearby circled Valery Bykovsky's Vostok-5. Their distance apart varied from 5 kilometres to several hundred, offering a variety of conditions for testing space communication systems. Valentina manipulated the manual attitude control system, enjoyed her unusual position and sang songs. During the 49th orbit the command was given from earth. There followed 16 minutes of descent, and then touchdown. Behind lay two million kilometres and 70 hours 50 minutes of space flight.

The news conference in the main auditorium of Moscow University was also an exciting experience. The overflowing hall hummed. Photographers ran backwards and forwards aiming their cameras at her and dropping to their knees to get a better angle. People stood in the aisles, listening attentively with bated breath, afraid of missing a single word. Valentina, slightly flustered, twirled a pencil in her hands. Bykovsky, next to her, whispered something to Nikolayev. Mstislav Keldysh, President of the Academy of Sciences of the U.S.S.R., presented Tsiolkovsky medals to the two latest cosmonauts.

Then came a world tour. The first woman in space was welcomed enthusiastically in Bulgaria, the GDR, Poland, Czechoslovakia, Cuba, the United States, Indonesia, India, Ceylon, Nepal, Burma, Ghana, and Algeria. Queen Elizabeth of Great Britain greeted her. There was admiration for the Soviet people, Soviet technology and the Soviet system that had made possible such brilliant triumphs in outer space.

The whole nation celebrated the marriage of the two space heroes Valentina Tereshkova and Andrian Nikolayev. The Wedding Palace, where the ceremony was held, swarmed with guests, and a crowd gathered at the doors to congratulate the newly-weds. On June 8, 1964, the first cosmic dynasty came into being with the birth of Lena Nikolayeva. What wondrous trails she may blaze in the future.

THREE MEN IN A SPACE SHIP

And then came the day when three men at once boarded a space ship, the Voskhod. Three men, three lives. An airman, a scientist and a doctor. Two of them were nearing forty, and the third was twenty-seven. Different roads had brought them to the Voskhod flight cabin.

Vladimir Komarov used to live in an old house in an old Moscow street running parallel to what is now Peace Avenue. Today a huge obelisk stands at the end of Peace Avenue commemorating the introduction of the space age, and Komarov's name is engraved on its base together with those of the other Soviet cosmonauts.

Konstantin Feoktistov was born in Voronezh, several hundred miles south of Moscow, into an accountant's family. His interest in outer space began when as a boy he read Konstantin Tsiolkovsky's science-fiction story, *Outside the Earth*, which tells of the flight of a multinational team of scientists in outer space.

When the war began Boris Yegorov was only five years old. Komarov joined an aviation school in 1942, from which he graduated three years later. Feoktistov saw action at the front in 1942, as an army scout. He crossed the front line several times until one day the nazis caught him. They made short work of him and shot him in the back yard of a gutted house. But Feoktistov remained alive and managed to get back to his unit. In 1943 he entered the Bauman Higher Technical School in Moscow, graduating from there six years later. He worked for a while at a factory and then joined a research institute. In due time Komarov became a fighter pilot, finished the Zhukovsky Air Force Academy, and finally joined the team of professional spacemen.

Feoktistov went in for science. In 1955 he took his Master of Science degree, and wrote several scientific papers. He was awarded two Orders of the Red Banner of Labour for his research work.

By then Boris Yegorov, too, had begun his career. He was a medical graduate, and went in for space medicine in 1961. An active, energetic young man, he is a keen mountain climber and has climbed several peaks in the Caucasus Mountains (which he subsequently had the opportunity of viewing from far above).

Three men. Three lives. Three professions. And, essentially, a common destiny. Each one pursued his calling, which in each case led him to the cosmodrome.

On October 12, 1964, the three-man Voskhod took off for its day-long flight. The enterprise had many remarkable features. The vehicle was launched by a much more powerful rocket than any before, and was like a flying laboratory. The cosmonauts were not dressed in cumbersome space suits with airtight helmets, and so they could carry out their various duties with greater ease. One steered the ship and could not hide his delight at the ease of its performance. Another carried out technical investigations. The third took blood tests and looked after the physiological reactions of his flight companions.

The orbit of Voskhod-1, too, was different, and it climbed to an altitude of more than 400 kilometres. Re-entry and landing were effected not by catapulting from the cabin and descending by parachute, as in the previous space flights, but without leaving the capsule, which touched the ground so softly that it hardly left a mark.

Several days later the heroes stepped from the air liner that had brought them to Moscow's Vnukovo airport. It was rather strange to see two men in civilian clothes flanking lieutenant-colonel Komarov on the red carpet. Their tailored suits and homburgs seemed to say: "No, we aren't really cosmonauts. We're just like the man next door, who may also be preparing for a space flight soon."

This, probably, is the most remarkable aspect of the Voskhod-1 flight. Gagarin, the idol of the space-age boy, is a symbol of the heroic aspects of space flight. Now outer space has come nearer the reach of the daily run of men; doctors, scientists and people of other professions. As the Italian author Gianni Rodari remarked, "It was once said that all roads lead to Rome. Soon we shall be able to say that all roads lead to outer space." Nowadays any one may hope to make the trip some time.

SPACE FLIGHT BEGINS WITH VOSTOK

In the future Museum of Astronautics the Vostok space ship will occupy its place, in the section devoted to the "early days". People will never cease to marvel at the achievement of human genius, which in the mid twentieth century created this remarkable piece of equipment.

The basic parts of the spacecraft are a pressurized cabin for the astronaut which contains the life-sustaining units, the instrument compartment, and the retrorockets of the braking system. This appears simple enough, but it took the combined efforts of many scientists, coupled with the latest achievements of physics, chemistry, metallurgy, electronics, biology and medicine.

Chemists and metallurgists had much to do in building a suitable outer shell and producing heat-resistant glass for the three portholes. This meant that the cosmonauts could observe the earth even during the final stages of the descent through the dense layers of the atmosphere, when the capsule heated up to a red glow.

Various systems and gadgets had to be devised against unforseen contingencies of all kinds. Such a seemingly simple thing as the pilot's seat is actually a complex piece of equipment with a detachable back, belts for strapping the pilot down for ejection and descent by parachute, the parachute itself and the seat ejection unit.

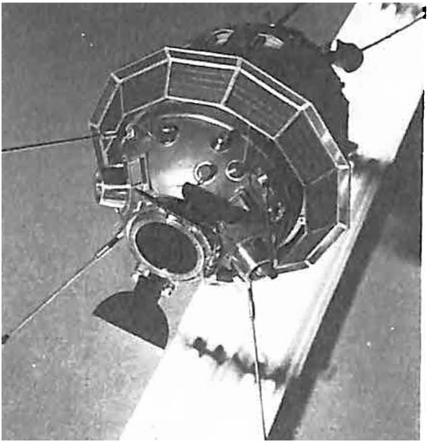
Anything can happen in outer space. An astronaut may not land at the designated point, but may find himself in a desert or at sea. He must be able to notify rescue teams of his whereabouts and look after himself until they arrive. And so the seat also contains an emergency supply of food and water and two portable radio transmitter-receivers.

In front of the seat is the manual control system. Not a single motion of the pilot nor the slightest deviation of the ship should escape the eyes of those on earth. There is therefore a two-way system of radio telephone communication and two television cameras giving two views of the astronaut at right angles. Numerous pickup sensors register all his physiological reactions. In short, the scientists on earth are hardly aware of the distance separating them from the space vehicle. Moreover, the telemetering system relays a continuous stream of information on the functioning of the space ship systems and the parameters of the orbit. This information is processed by computers on earth, which then relay back to the ship forecasts of its further motion.

In flight the orbiting space ship must be specifically oriented with respect to the sun and the earth. This is especially important at the moment when the retrorockets are to be switched on. The Vostok had an automatic attitude control system locked in on the sun, and a manual control system for orientation with respect to the earth through a special optical device.

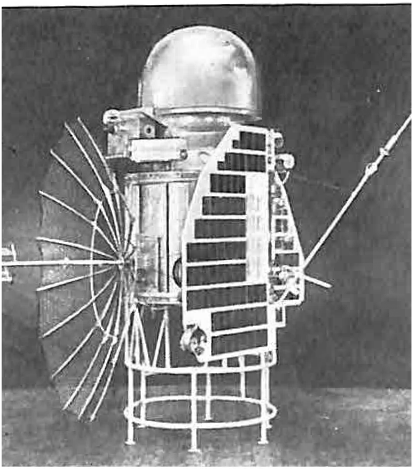
The retrorockets are probably the most important units of the space ship. They must be compact and light, for in space flight every ounce counts. They must ensure split-second timing of the retardation, for on this will depend the accuracy of touchdown.

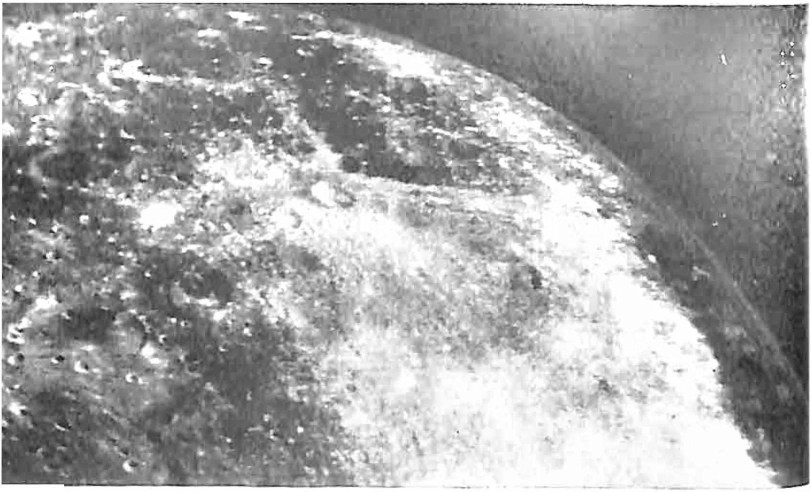
The Vostok retrorockets demonstrated their worth on all six flights. But even if they had malfunctioned, the vehicle is provided with an emergency re-entry system which makes use of the atmospheric drag. However small the chance of a breakdown in the retrorocket system, this contingency was also provided for.



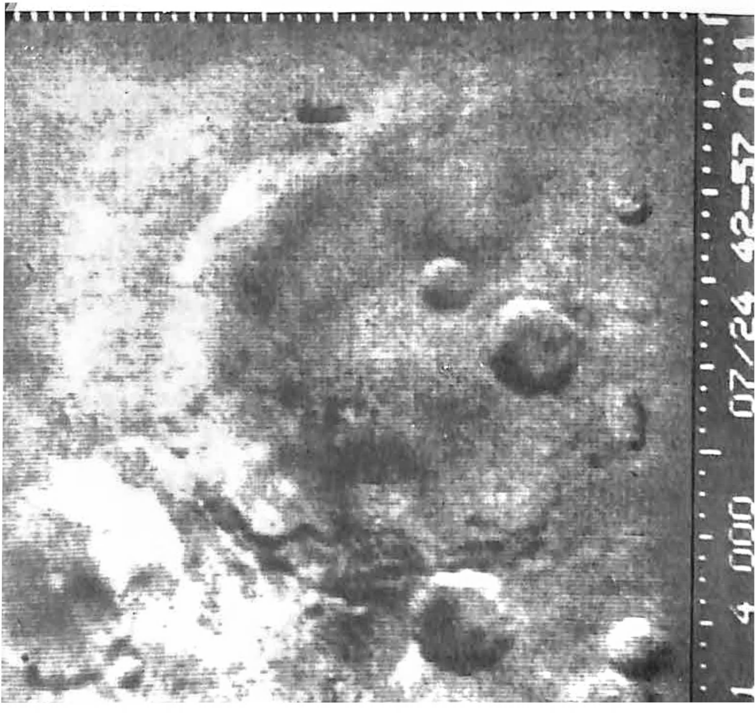
The camera on the Luna-3 sent the first pictures of the moon's reverse side to earth

The Soviet spacecraft Venus-1, the pioneer of interplanetary flight





The moon and Mars look a bit alike, don't they?



MAN FLOATS IN SPACE

The saying that it is always easier for those that follow is hardly applicable to Soviet cosmonauts. At least, not until space flight becomes part of the daily routine and space ships are travelling along regular scheduled routes like commercial aircraft today. And although the scientists and cosmonauts take into account the experience of each preceding space flight down to the minutest detail, each time the tasks are essentially new and more complex.

Space flight continues to be largely a flight into the unknown. Pavel Belyayev and Aleksei Leonov had plenty to do and think about before undertaking their ambitious mission on March 18, 1965.

It looked like a miracle. A man was actually floating in outer space. And that man was Aleksei Leonov, a Soviet cosmonaut. People saw it with their own eyes on their T.V. screens; how he emerged from the hatch of the Voskhod-2 space ship and floated and tumbled on the end of a kind of umbilical cord that kept him from drifting away from the vehicle.

At that exciting moment most people probably forgot about Pavel Belyayev, commander of Voskhod-2, who continued to carry out his important assignments inside the space ship For it was his duty to control and orientate the vehicle, analyze the instrument readings, receive and carry out commands from earth and do many, many other things, besides, of course, helping Leonov in his exit from and re-entry into the space ship cabin. And he was also ready, should the need have arisen, to leave the cabin himself and go to Leonov's aid.

Pavel Belyayev, son of a country surgeon's assistant, spent his boyhood in the backwoods of the Vologda Region, in the north-western part of the Soviet Union. The future cosmonaut passed through a rigorous school of life in which his courage, grit and willpower were tempered. His character was moulded in his work as a factory lathe hand, in action at the front, where he went as a volunteer in 1943, at a military school and at a Naval air force unit. At the time he was accepted by the cosmonaut training centre he was a squadron commander. His biography appears to be a smooth, steady upward climb. But the amount of persistence, willpower and perseverance he put towards achieving a goal can be gleaned from but one episode. At the beginning of his training at the cosmonaut school Belyayev suffered a grave setback; he broke a leg in a faulty parachute jump. The doctors said that he would have to give up both space and aeronautical flight. Belyayev, very courageously, agreed to undergo an extremely risky operation. For many days he struggled for his right to remain in line, and he won through.

Aleksei Leonov was born in Siberia. He was clear about his future from childhood, and aircraft models, gliders, and books and manuals on aeronautics have been his great interests for about as long as he can remember. A natural sequel to this was his graduation from the Chuguyev Air Force school with a fighter pilot's certificate. When he came to the cosmonaut centre he joined the other cosmonauts, some of them already world famous, in their strenuous training routine. Leonov's favourite hobby is drawing, and he is more than just a dabbler. His drawings show fine taste and the accurate eye of an artist. This talent later helped him to give a glowing description of the remarkable picture that unfolded before him, the first human being to view it from open space.

Thus it was that one day in March 1965 the world was electrified by the flash report: "In the course of the flight of the space ship Voskhod-2 a man has for the first time left the vehicle and stepped into outer space. During the second circuit of the globe cosmonaut lieutenant-colonel Leonov, second pilot, wearing a special suit with a self-contained life-supporting system, went out into cosmic space, moved up to 5 metres away from the ship, carried out a set of investigations and observations and returned safely." People could see what it was like on their television sets.

This first direct confrontation between man and the universe required more than an intense concentration of willpower. It required what scientists call "space courage" to overcome man's natural "support reflex" and keep one's head in such unusual conditions where a single sharp movement could be fraught with grave consequences.

Newspapers the world over came out with banner headlines: "Man Steps into Space!", "Opening the Door into Space", "New Stage in Space Conquest", "The Russians Do It

Again". Congratulations streamed in from statesmen and ordinary people of a hundred different countries. Leonov's feat was duly appraised by astronomers and mathematicians, experts in space medicine and telemetric communication systems, meteorologists and physicists. The moon, that cherished first goal of interplanetary travel, came closer within reach. Astronomers who had been debating the pros and cons of establishing space observatories in orbiting stations or on the moon began to favour the latter. Leonov's twenty-minute jaunt in space demonstrated that it was possible for men to carry out space ship servicing, maintenance and docking operations during orbital flight. We can already imagine cosmic builders floating in outer space. They will handle huge loads, weighing many tons on earth, like a bundle of feathers.

One can understand the American's desire to emulate the exploit of the Soviet cosmonauts. On June 3 of the same year, a Titan-2 rocket carried aloft a Gemini-4 space ship with astronauts James A. McDivitt and Edward H. White on board. Major White was to repeat Leonov's exploit. Before that McDivitt attempted to close in with the Titan carrier-rocket. However, the Titan's orbit lowered so rapidly that he had to give up the attempt.

The smaller size of the American space ship forced the designers to do without an air lock, which the Voskhod-2 had, and the cabin had to be depressurized for White's excursion. The desirability of an air lock was made apparent when the astronauts had some trouble in closing the hatch after White's return.

Outside the spacecraft White tested a jet propulsion unit designed to enable future spacemen to manoeuvre and move about. Gemini's flight lasted four days. The capsule landed in the Atlantic ocean, where the men were retrieved by a helicopter which took them to an aircraft carrier assigned to collect them.

The term "man in space" has taken on a new meaning, for now it really means in space, not just inside the cabin of a space ship. The problem of reaching the moon and disembarking there has thus acquired new perspective. Scientists, and not only science-fiction writers, are confident that this will be achieved in our century, if not in the present decade.

WITHOUT LEAVING THE EARTH

Preparations for any expedition begin long before it sets out. The itinerary must be decided, the participants selected and the necessary food, clothing and emergency stocks acquired. This was so when Amundsen was preparing to reach the South Pole and when Henri Lhote went to copy the rock drawings he discovered in the Sahara. However, the preparations did not always include all-round physical training of the participants. The essential requirements were knowledge, skill and, mainly, a high degree of enthusiasm. Very few outstanding explorers and travellers paid much attention to their physical fitness. Amundsen, a man of rare purpose, once he had decided to be a polar explorer, began by preparing his body and organism for the task.

"I decided that I would be a polar explorer.... I immediately began to prepare myself for the life of an explorer.... Although I did not care much for football as a sport I began to play it in order to train my body and develop stamina.... Between November and April, whenever I had time from school, I went skiing....

In those days homes were not well ventilated in winter and people thought I was practically mad because I slept with an open window. In this way I carried out part of my training."

Amundsen worked as a carpenter at a shipyard. He spent several years at sea as a sailor before taking examinations to become a mate and then a skipper. For, before the days of aeroplanes, being a polar explorer meant being a sailor.

Then, when aeroplanes appeared, Amundsen learned to fly, becoming the first Norwegian civilian flier. He studied books on terrestrial magnetism and the techniques and methodology of magnetic observations. He also read travel accounts, especially those with a tragic outcome. (Amundsen always studied the mistakes of others carefully, which is why he rarely made any himself.) His journey to the South Pole can be compared, in the words of the Russian polar explorer Vise, "with a faultlessly played musical piece in which every note and every bar are known in advance and carefully considered by the performer."

When Dr. Bombard was preparing for his lone journey across the Atlantic he not only studied ocean currents and the minimal physiological requirements of the organism. "I tirelessly squeezed moisture out of various fish, seeking the best results from the point of view of both taste and quantity."

But how should one go about training travellers who planned to overcome the earth's gravity and penetrate a void where there were endless hazards?

In conditions of zero gravity, coordination and orientation in space are essential. Acrobatics, swimming and skiing are therefore important. Endurance is developed by subjecting the body to prolonged loads. This points to cross-country running, sculling and cycling. Quickness and sureness of reaction will be improved by boxing, basketball, fencing and tennis. The value of mountain-climbing is self-evident, and the parachute to the cosmonaut, like the car to the layman, is not a luxury but a means of travel. Everything mentioned above forms part and parcel of the rigid daily training routine.

There are also special training sessions. There is the centrifuge for developing the body's resistance to acceleration loads. First it is just a matter of getting used to it; a 2 G-load is quite bearable. Three Gs are more noticeable, while five are definitely unpleasant. Day after day the future astronaut is whirled round in the centrifuge, and the speed of rotation, and hence the G-load, are steadily increased.

It has been suggested that if a man were to lift a calf every day from its birth, the time would come when he would be lifting a cow. But there are no cow-lifters in the world. Similarly there is a limit to man's powers of endurance to G-loading, even if the load is increased very slowly.

When the astronaut has become accustomed to fairly big G-loads he must learn to move and work in conditions when his weight is several times greater than normal. He has to turn his head, raise his hand, press a button and throw a lever. It proves to be hard work.

Throughout this physical training the astronaut is taught variety of special subjects: space ship steering and control, radio communication, instrument reading and many other things that he must know about in outer space.

Later on they are all mixed together: G-loading, attitude control, radio communication, etc.

Added to the general training routine there are various special exercises depending on individual performance. Thus, for example, Nikolayev would fall asleep in the "silence chamber" and simply couldn't keep himself awake. This drawback was soon overcome and he learned to wake up at the right time even without an alarm clock.

Training methods are changed as a result of experience gained in real space flight. For every flight is a step towards the next one and has a direct bearing on the preparation of future astronauts. Titov, for example, had experienced an illusion of turning upside down during weightlessness. The instrument panel seemed to float up and hover above him. He soon overcame the unpleasant sensations, but the scientists on earth took it into account and revised the methods of training the balancing organs. Titov's observations were also useful to doctors studying motion sickness.

Another important element of preparing for space flight is "isolation training". A man is left alone in a mock-up of a space cabin or simply in a room sealed off from all external stimuli. When the American doctor Donald Hebb placed healthy men in conditions of complete isolation they soon developed hallucinations and abnormal behaviour. It has been found that hallucinations, neuroses and other psychological breakdowns do not develop if the conditions of "super rest" are removed. That is to say, a person's mind will function normally if it is occupied. The person may be engaged in taking temperatures, checking his pulse, noting the time, making notes, etc. Activity in isolation and solitude, and doing something with a purpose are reliable defences against psychological breakdown.

And last but not least, an astronaut has to undergo "eating training" as well. This should not cause surprise. Fridtjof Nansen, for example, trained himself (and his wife too) to eat pemmican. Astronauts must be ready to consume, and like, tubed and canned meats, soups, fruits and other preserves.

The last stage in an astronaut's training is a complete (as far as possible) simulation of the conditions of space flight, with isolation in a pressurized cabin, G-loading, manipulation of controls, maintenance of radio communication, etc.

CENTRIFUGAL TRAINING

There are many examples of centrifugal force in everyday life, such as a merry-go-round or a car swerving round a sharp bend. Centrifugal force is used in training astronauts. It helps to simulate on earth the G-loading that occurs during the acceleration and re-entry of a space vehicle. The machine used to reproduce this force is called a centrifuge. It consists of a steel frame pivoted on a vertical shaft with a seat mounted in a set of gimbals so that it is free to turn in any direction around its axes. The motor is switched on and the frame starts whirling round and round. An accelerometer records the G-load bearing down on the astronaut. Modern centrifuges can increase a man's weight as much as forty times.

Doctors observe the astronaut over closed-circuit television, his reactions are filmed and the effects of loading on his bodily functions are recorded by temperature, blood pressure and other sensors. The man can also report his sensations by telephone.

In some centrifuges the seat is placed inside a spherical airtight capsule in which temperature, pressure and the astronaut's position can be changed during the exercise.

OUTER SPACE IS NEXT DOOR

A heavy, hermetically sealed door opens and an astronaut in full space rig steps ponderously out of the chamber. He lifts the visor of his helmet and smiles. He has just returned from a simulated flight into the stratosphere, to an altitude of 50 kilometres. A doctor examines him and asks him how he feels.

Ever since men began to fly higher than two or three kilometres it has been necessary to train airmen for high altitudes. This is done in an altitude training chamber, or stratotrainer, in which the pressure of the air is lowered to correspond to the altitude being simulated. A further development, introduced for training astronauts, is the thermal stratotrainer in which the temperature also is regulated to simulate space flight conditions. Modern training chambers have a volume of up to 50 cubic metres, which is quite a comfortable room for one man. As powerful vacuum pumps evacuate the air from the chamber it "gains altitude". Heating or cooling units simultaneously change the temperature. A doctor observes the pilot through many-layered glass and talks to him over a telephone. There is an emergency valve connecting the chamber with the atmosphere. If the pilot's suit suddenly becomes depressurized the pressure inside is, with the precautions, brought up to atmospheric.

WHEN THE BRAVE SHIVER AND SHAKE

The new high-speed aircraft was performing beautifully. It climbed rapidly, continuing to accelerate. Then all of a sudden the machine reared like a startled horse and began to vibrate so violently that the pilot was unable to keep his hands on the control column. He blacked out momentarily, and it seemed that the machine would fall to pieces. When at last he was able to regain control and land the aeroplane it presented a strange sight; its smooth, glittering outer skin was corrugated, and there were numerous cracks on the wings and fuselage. The damage was caused by what is known as flutter, one of the greatest perils of high-speed aicraft. It may last only a few seconds but can be sufficient to break off the wings and rip the fuselage to pieces.

Vibration and resonance, when they get out of control, may become real calamities. They increase machine wear and metal fatigue and reduce the machine's lifetime. Vibration is also one of the evils that develop at cosmic speeds, and the first astronauts were quick to feel its effects. Evidently, then, an astronaut must be prepared to control vibration and he must train his body to resist its effects. This is done on a special vibration stand. It consists of a platform on which are mounted all the instruments to be tested for resistance to vibration and a seat in which the pilot is violently shaken about. Sensors attached to various parts of his body record his respiration, heartbeat, brain waves and other responses to the effects of vibration.

ONLY FOR STRONG NERVES

Total isolation.

Total silence.

And total darkness. Darkness of absolute blackness.

Only the instruments buzz and hum monotonously.

These are the conditions of space flight, and it is primarily these conditions that strike at the astronaut's nerves. Great psychological tensions may develop in the silence and solitude of the cosmic void, resulting in visual and aural hallucinations, to say nothing of other as yet unknown reactions.

We frequently underestimate the dangers of unusual environmental factors. But people like Nansen, Amundsen and Scott, who cannot be suspected of lack of courage, speak of the oppressive effects that the polar wastes have on the mind.

In ordinary life we do not really know what darkness is. The blackest of nights is never so dark that it is impossible to see the outlines of objects. Our eyes are capable of adapting to minimal lighting conditions.

In outer space the bright specks of stars gleam against a background which is totally black. The eye sees a black void that starts at the very edge of the blinding disk of the sun.

The nerves are tensed in these unusual conditions. The monotonous droning of the instruments only increases the tension.

If you are sitting and reading in an empty room the buzzing of a single fly can be maddening. The more you try to concentrate on the book the more the buzzing resounds in your ears. So the monotonous sounds of the instruments in an otherwise still space ship capsule keep hammering on the nerves. This is one of the effects of a prolonged stimulation acting without a break on the same nerve centre.

To these conditions of space flight is added the weird feeling of weightlessness, the absence of gravity, which it is impossible ever to experience on earth. You no longer feel the seat beneath you and seem to be hovering above it. A drop of spittle that has escaped from your lips floats before your nose like a mute rebuke. Weightlessness affects different people in different ways and it is impossible to predict its psychological effects; nervous systems are highly individual pieces of the human machinery and people often tend to react differently to external stimuli.

Gagarin related: "I felt fine. It suddenly became so easy to do things, and there was a general feeling of unusual lightness. This is a very remarkable feeling. My hands and feet weighed nothing, and felt as if they no longer belonged to me." Gagarin, as we see, enjoyed the state.

But here is another kind of reaction. Gherman Titov was weightless for 24 hours. "The transition from high G-loading to weightlessness created a sensation of suddenly falling head downwards. The instrument panel seemed to move up above my head." Although the unpleasant sensations later passed, you will agree that it requires strong nerves to stand up to them.

What then can one expect when besides silence, darkness and weightlessness there is the additional strain of solitude, psychologically probably the most dangerous state of all? Conversely, the enforced company of one person (as is the case in a two-man space flight) can also have some strange effects.

When Nansen (Fridtjof Nansen himself!) and his companion Hjalmar Johansen (all-round athlete, lieutenant of the Norwegian army, university student and a man of calm and confident courage) embarked on their great eighteen-month trek to the Pole from the ship "Fram" frozen into the Arctic ice, the time came when they got so annoyed with each other's presence that they spoke only once or twice a week. and even then addressed one another as "Mr. Expedition Chief" and "Mr. Head Navigator". When they returned home Nansen and Johansen continued to be great friends. (Nansen described these experiences in a lecture entitled "What We Don't Write About in Our Books".)

Obviously, such psychological breakdowns may lie in store for astronauts. Or take ordinary fear. Every man experiences fear, but a brave person is able to control it. One of the sources of fear in outer space is the thought of being unable to get back to earth.

The best way of combatting psychological breakdowns of all kinds is to create the best possible flight conditions and undergo intensive training. Obviously, though, it is impossible to foresee every contingency. One can never predict the nature of an emotional reaction to a freak occurrence or a weird chain of events.

And last, but not least, we do not know how the absence of normal living patterns will tell on a man in space; there is no day and night and no diurnal temperature fluctuations.

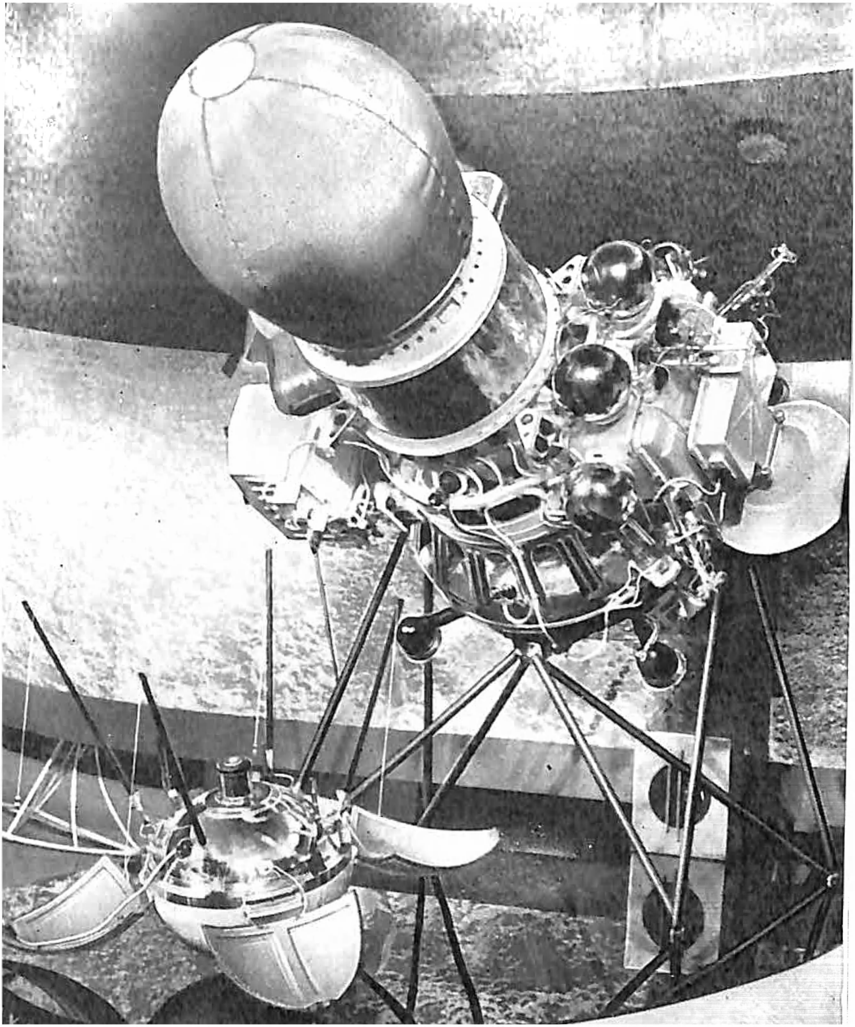
An astronaut's nervous system begins to respond to the strain of space flight long before his space ship carries him aloft. Thus, four or five minutes before take-off, Nikolayev and Popovich registered an increase in pulse rate from 70 to 115-120 per minute, and a further increase to 130-140 when the rocket motors were fired (in the case of Gagarin and Titov it was 160).

Differences in temperament and mentality were noticeable on the astronauts' return to earth. Nikolayev answered questions readily, but in curt, clipped sentences without much detail. Popovich, on the other hand, who is an example of the "artistic type" of nervous system, was emotionally moved and described his impressions in great detail, speaking excitedly and gesticulating with his hands.

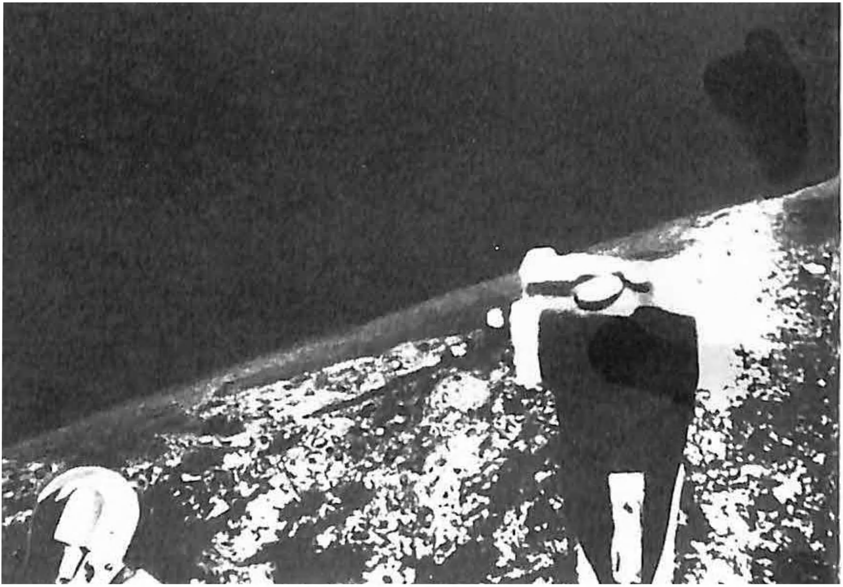
In conditions of solitude and silence, and with the realization that one is isolated from the earth, radio communication is of tremendous, if not decisive, importance. In outer space a human voice from earth can be an excellent psychological sedative. Of course, as time goes by the attitude towards space flight of astronauts and laymen alike will gradually change, just as the attitude of men towards the speed of travel changed with the invention of the steam engine, the motor car and the aeroplane.

Gherman Titov, speaking to a group of Soviet writers in June 1962, commented: "What struck me most was how small the earth is. There really is no place for war on it."

Obviously, when people see for themselves the puny size of the earth, human psychology



*Luna-9 was designed for lunar soft-landing.
And it surely did not let us down*



Here it is, the Ocean of Storms (Oceanus Procellarum). For all we know it might serve as a foothold for the first men on the moon is bound to change. The psychology of the space age is being moulded, new concepts are developing and old ones are passing away. The concept of war should be among the first to go.

READJUSTMENT

Rhythm. Morning, day, evening, night.

Rhythm. Spring, summer, autumn, winter.

This is not just a matter of light or dark, hot or cold. The whole organism functions differently in each of these periods.

Most infarctions of the heart occur at night, when the region of the nervous system that may cause spasms of the blood vessels becomes more active.

Rhythm. Gastric ulcer usually gets worse in spring and autumn (even if the weather is autumnal all winter or spring-like all summer). This means that some kind of rhythm comes into play.

The moon waxes and wanes from new to full and back again.

There are indications that the exacerbation of many diseases occurs during the New Moon.

The organism grows accustomed to rhythm. An Eskimo is used to a six-month night and a six-month day; a Congolese from the equator, where days and nights are each approximately twelve hours long all the year round, would require some readjustment to adapt himself to the Arctic rhythm.

If you are used to eating at three p.m., you begin to feel hungry as the hour approaches. If you usually go to bed at eleven o'clock, sure enough, when bedtime comes your eyes begin to get heavy (just as they would at the North Pole, where the sun would still be in the sky at 11 p.m.). These are all the results of a habitual rhythm.

A habitual rhythm. A habit is, essentially, nothing but a conditioned reflex. This means that to some extent conditioned reflexes constitute the basis of the rhythm of life. Biological rhythm depends on the alternation of day and night, winter and summer. Habitual rhythms depend on the totality of the body's conditioned reflexes.

An astronaut's biological rhythm breaks down. There is no day or night. Or rather, in the case of orbiting space ships, they alternate very rapidly; every 88 minutes for the Vostok series.

The temperature in the cabin is uniform. Nothing changes. But the habitual 24-hour rhythm can be preserved. This is done by including in the astronaut's training the development of a new habitual rhythm, and new conditioned reflexes. Thus Nikolayev was trained (that is to say, he developed a conditioned reflex) to wake up exactly on time.

In outer space there is no day or night, summer or winter. But inside the cabin there is a clock which measures equal lapses of time. In the course of his training a candidate astronaut spends a great deal of time in a sealed cabin completely isolated from the outer world.

He grows accustomed to the solitude, the monotony and the absence of rhythm. If he does not, he cannot be an astronaut.

HEALTHY PATIENTS

The combination of words in the heading is a bit paradoxical, but space medicine, in fact, deals only with healthy patients. Space medicine is a branch of space biology, which studies the effects of various extraterrestrial factors on a normal organism. It involves two basic modes of investigation.

In one, different elements of space flight are simulated in laboratory conditions and their effects on the body determined. Astronauts are selected and duly trained. The physicians are directly concerned with the creation of comfortable conditions in the space cabin, and with the necessary microclimate; they have a say in the manufacture of pressurized suits, space cookery and other apparently non-medical problems.

The second mode of investigation is direct observation, first of test animals and then of people, in rocket flights and orbiting space ships. Doctors on earth keep a constant watch over the astronaut's condition. Electrocardiograms, pulse rate, blood pressure, respiration rate—these and other data are relayed to earth in a steady stream. Unlike the family physician, the space doctor is separated from his patient by thousands of miles. Nevertheless, he can give expert medical advice.

Investigations and observations make it possible to draw conclusions about the body's reactions at every stage of a flight. Different factors come into play in the different stages.

There is G-loading during ascent; the doctors must determine the best position for the pilot to assume.

At 15,000 metres atmospheric pressure is 87 millimetres of mercury, and breathing is impossible even if the air were of pure oxygen.

At 19,000 metres the barometric pressure equals the vapour pressure in the organism, and bodily fluids begin to boil.

Above 24,000 metres it is no longer possible to maintain a satisfactory inside pressure by pumping in air from outside; pressurized capsules are required with a system of chemical air regeneration.

At 36,000-40,000 metres cosmic rays begin to present a real threat to the astronaut's health, and higher still the action of ultraviolet rays is added.

At 100,000 metres meteors become dangerous.

Even higher there is absolute silence. Sound waves are not propagated. Light is no longer dispersed by the atmosphere. It is dark. Very dark. Pitch black. The feeling of the depth of space disappears. Unusual stimuli acting on the sense organs make it necessary to provide psychological protection for the astronaut.

Once in orbit weightlessness comes into play. It does not affect such vital functions of the organism as blood circulation, breathing or digestion. It can affect coordination of movement, and the space physicians must take it into account.

Failure to reckon with any of the active factors of space flight can be fraught with danger for the crew.

Space medicine incorporates practically all the medical and biological sciences. It is the youngest but also the most comprehensive of them all. The future is for space medicine, the medicine of healthy people. On earth it will help to evolve a completely healthy human race, a task as ambitious as space flight, if not more so.

ANIMALS HELP MAN

At the Sorbonne in Paris, where the great physiologist Claude Bernard worked, stands a statue of a frog, a bronze tribute to the hundreds of thousands of frogs that helped physiologists in their research. In the grounds of the institute near Leningrad where another great physiologist, Ivan Pavlov, once worked, there is a statue of a dog, symbol of the countless dogs on which he studied conditioned reflexes. Dogs also proved to be invaluable assistants in investigating the problems of space flight.

The scientists of long ago noted the similarities between human and animal organs and compared their functions. Observations conducted on animals were applied to the human body. The muscles, heart, lungs and other organs of various animals are analogous. Galen and Celsus used dogs to learn how to cure men. Harvey discovered blood circulation by studying animals.

When the normal functioning of the organism was fairly well known, scientists turned to investigating how it was affected by external influences. Animals have long been used for this in both laboratory and natural conditions. Miners would take canaries into the pit with them. If the bird drooped its wings it meant there was firedamp present; if convulsions developed it meant that the pit should be evacuated as quickly as possible.

Such a canary is needed to study the effects on man of the stimuli of outer space; to see how man will react to oxygen deficiency, reduced pressure, high speeds, weightlessness, cosmic radiation, etc. In preparation for manned space flight rockets carried aloft microbes, fruit flies, water turtles, mice, hamsters, rats, parrots, dogs and monkeys. It comes as no surprise, of course, that no animal is completely identical to man. That is why the most diverse representatives of the animal kingdom are sent up. A parrot's voice can be recorded on magnetic tape. Fruit flies are used to study the effects of cosmic radiation on heredity. In the Soviet Union dogs have been used extensively, and the dog Laika was the first living creature to fly aloft in an artificial earth satellite. There can be no doubt that grateful mankind will remember Laika forever.

THE INVISIBLE MONSTER

Centrifugal force, a huge, invisible monster, pressed my head between my shoulders and pushed me into the seat with such strength that my backbone bent and I groaned under the weight. The blood drained from my head and everything went black. This is how the famous American test pilot Jimmy Collins described the sensation.

The train starts and accelerates. Something pushes you gently in the chest and presses you back into your seat. It is such a common experience that you hardly even notice it. In an aeroplane it is different. Higher speeds mean new sensations. Acceleration loads attack the pilot like an insidious enemy who has awaited his hour. They hurl themselves on him when he brings his aircraft out of a dive or climbs steeply. They embrace the astronaut in an iron grip during the take-off of a space vehicle, in entering into orbit and during the return to earth. The limits beyond which the G-loads are lethal are determined in experiments in centrifuges.

An animal is strapped into the cradle of a centrifuge. Instrument readings say that the acceleration is five times the acceleration due to gravity (a load of five Gs). The oscillograph recording the action potentials of the heart shows a sharp slowing down of the heartbeat. In a few moments the experiment will have to be stopped if the animal is to endure the load.

The load was acting towards the head. When it was made to act in the opposite direction animals could withstand seven or eight Gs. If the position is changed so that the load acts not along the body but at right angles to it the body's resistance almost doubles.

The limits of human endurance have been established. The body weight of the first astronauts increased several times without their feeling any ill effects. Can human endurance be increased?

As far back as 1891, Konstantin Tsiolkovsky carried out an interesting experiment. Frogs and fish in water could withstand a 2,800-fold increase in weight. Much later similar experiments were carried out with people. A tank of water was mounted in a centrifuge and a man in a diving suit was placed inside. It was found that he could stand more than 13 Gs for five minutes, and this is not the limit. People will go to any lengths for science. They will even agree to embark on a space flight inside a water tank. The question is, of course, how will they work there?

THE DANGERS OF HEIGHT

People climbed mountains and found it hard to breathe; they gasped for air and developed splitting headaches. Some bled through the nose. When they came down again they immediately felt better. The ailment also passed if they could inhale oxygen. The sickness, caused by a shortage of oxygen in the blood, was called altitude sickness.

But what were the altitudes man had to deal with before? Even the summits of the Himalayan and Pamir mountains were conquered only recently. Today, however, 10 kilometres is the normal altitude for passenger air liners. Only with the coming of aeroplanes did the concept of real altitude sickness develop. It is called aerodontalgia, while the disease of mountain climbers is known merely as mountain sickness.

The needle of an altimeter climbs higher and higher. Altitudes of 20-25 kilometres are conventional for many types of aircraft. Astronauts have been more than three hundred kilometres up. Altitude sickness has acquired new features which were not known when it was merely mountain sickness. At high altitudes the bodily fluids begin to boil. At 25 kilometres the atmospheric pressure is only 19 millimetres of mercury and water boils at 22 degrees Celsius. At 30 kilometres the boiling point is 10 degrees. When these altitudes are simulated during experiments in pressure chambers the test animal, a rabbit for example, begins to swell. The water beneath the skin, inside the fatty cellular tissue of the body, in the blood and all other tissues begins to behave just as it does in a boiling kettle. Man must be protected against this. The pressurized cabin of an aircraft or space vehicle, in which the pressure and composition of the air remain constant at all altitudes, and pressurized suits are firm guarantees against altitude sickness.

ZERO GRAVITY

People have always respected weight. A weighty argument is convincing. Lightness is less dependable. And weightlessness was unknown. On earth it can be achieved only for a few seconds, in a diving aircraft or a falling lift (if anyone would care to experience the sensation). Then on October 4, 1957, the first Soviet sputnik was sent aloft. Less than four years later the first man flew in space.

Yuri Gagarin was weightless for 95 minutes, Gherman Titov, for more than a day, and Valery Bykovsky, for almost five days, with no aftereffects to speak of. Some experts, however, consider that very long spells of weightlessness may cause disturbances in the organism. For example, an astronaut may lose some of his locomotor skills and may have to learn to walk again when he comes back to earth.

RADIOTELEMETRY

The meaning of radiotelemetry can hardly be explained in a few words, although essentially it denotes the science that deals with measurement (from the Greek "metron", measure) and the transmission of the data over a distance (from the Greek "tele", far off)—not in any old way but by radio.

What is measured in space flight? It would be simpler to say what scientists are *not* interested in at the present stage of space exploration. They measure everything conceivable, and some inconceivable things, too. They note the colour changes of a space ship hull during flight and the effect this may have on the crew, or an astronaut's mood (a continuation of tests carried out in the space simulation chamber on earth), or even the flow of time.

Such quantities as the astronaut's pulse, rate of respiration, cabin temperature, pressure and humidity are obvious musts. Measurement alone, however, is not enough, and the data must be transmitted back to earth. Present day space ships usually have only one transmitter, and it must transmit readings from many sensor elements. This is achieved in the following way.

Each sensor is connected to one of many contacts arranged in a circle. A sliding contact moves round the circle, closing the circuit through each of the stationary contacts in turn. When the circuit is closed the signal from the corresponding sensor passes through the transmitter, which broadcasts it to earth:

"Temperature, 20; pressure, 730; radiation, 40."

The signal reaching the earth passes through a similar sliding contact revolving in step with the one in the transmitter. The operator reads off the reports:

"Temperature, 20; pressure, 730; radiation, 40." (He knows, of course, that the numbers are, respectively, degrees Celsius, millimetres of mercury and milliroentgens.)

Actually, though, the data coming in at the receiving station is not so easily read off. It appears in the form of pips on oscilloscope screens corresponding to various levels in the measured quantities. As the temperature increases a stronger electric pulse comes in. If the radiation becomes more intense the earth-bound observer can see it on the screen.

THE PROMISE OF ANABIOSIS

Anabiosis is a state of the organism in which vital processes are so slow as to be almost nonexistent. At first glance the organism seems to be dead, but this is not so. There is just a glimmer of life in it. Energy expenditure is nil. Can this continue forever? Could this be the ultimate triumph over death? But what sort of triumph is it, if life, too, is virtually nonexistent!

Be that as it may, anabiosis offers plenty of scope for flight of fancy. A resuscitated pterodactyl, for instance. Or perhaps excavations in the Sahara might uncover a man in a state of anabiosis. He comes to life and turns out to be one of the makers of the ancient rock paintings. He tells us the meaning of the drawing of a man in what looks like a pressurized suit (the scientists have even dubbed it the "Great Martian God").

Then there is travel to other worlds. The journeys may last a very long time. Tens, hundreds and even thousands of years may pass before earthmen reach their destination. A "super-cooled" crew is one way out; the astronauts would make most of their trip in the state of total rest offered by anabiosis, thereby preserving their vital forces for future explorations. This, of course, belongs to the realm of fantasy, but these days the gap between fantasy and reality is not great.

The basis of anabiosis is the dehydration of cell protoplasm by drying, increased salt concentration or reduced temperature. The Hamburg weekly *Die Zeit* published an article by the

German scientist Dombrowski. A subterranean bed of salt, where an ancient sea once lay, was found to contain bacteria of many hitherto unknown species. More important, some 40 of them were resuscitated.

Living cells were brought to life after lying dormant for some 200 million years. It seems incredible. Dombrowski tried putting them back into their anabiotic state by placing them in a concentrated saline solution. Later he revived them again.

We do not as yet know how to induce a state of anabiosis in higher animals, but some advances have been made. A reduction in temperature causes a corresponding reduction in the body's metabolism. Hence the oxygen requirements of the tissues and cells are much lower. Oxygen is carried to the cells by the blood, and so it follows that the blood circulation, and hence the heart, can be "turned off" at least for a time.

This reduction of temperature in anaesthesia, known as hypothermia, is used in some operations on the heart. Metabolism is reduced, the heart is halted for a very brief period and cut open, the necessary surgical manipulations are carried out, and then it is sutured and "started" again.

Stopping the heart! The heart, which has no right to stop. It starts beating 20 weeks before birth and continues steadily all through a man's life without a moment's respite. Truly, the idea of stopping the heart borders on the fantastic, yet it is being done.

FINDING ONE'S WAY

It is an unpleasant experience to get lost in a forest. Even if you chance upon a road or path you have no way of knowing which way to go to reach human habitation. All that you can do is raise your voice and yell "Haloo!" The more experienced know how to determine the directions of the compass. In a forest this is not too difficult, even without a map and compass.

A man can locate his position on land with a map and compass. But these are not enough for a ship's navigator; he needs not only a quadrant or sextant but also the stars at night and the sun during the day. That was in the old days. Today in order to chart a ship's course accurately and know its position at any time the navigator also uses sailing directions, astronomical tables and radar. In addition there are many lighthouses to guide him.

But who will light a beacon for space travellers? An inhabitant of the Andromeda nebula? Yet the position of a space ship travelling at tremendous speed must be known precisely at every instant. A special system of attitude control has been developed to change a space vehicle's position in space and alter its direction.

On October 4, 1959, a Soviet automatic space station was launched to take pictures of the reverse side of the moon. The orientation system was switched on by command from earth when the station lay roughly on the straight line connecting the sun and the moon. The invisible side of the moon was lit up by the sun and the cameras were trained on it by turning the station as a whole. First the orientation system halted the station's random tumbling around its centre of gravity, which had begun when it was separated from the carrier rocket. Then optical solar sensors gave the signal for the station to turn its "bottom" to the sun. A specially devised view finder then "locked" the station in position so that the cameras faced the moon, and gave them the "go ahead" to start shooting. Gyroscopic sensors held the station in position and a unit of logical electronic computers and attitude control motors carried out all the commands of the automatic sensors. The covers were automatically removed from two lenses and the film drawn into place. Instruments computed and set the required exposure, released the shutter and developed, fixed and dried the film in an automatic darkroom. When the photographing ended the orientation system was automatically switched off.

Luna-3 swept round the moon and headed back to earth. Soon the command was given to relay the pictures back. The television transmitter used for the purpose had a power output of only a few watts, which is a small fraction of the output signal of commercial T. V. centres. These weak signals had to travel over a distance of 470,000 km. Nevertheless, they were not lost. They were picked up and amplified on earth and a clear image appeared on the television screens from which the first ever pictures of the far side of the moon were taken.

The development of a reliable attitude control system for a space ship is a difficult job.

Pendulum devices, for example, are unsuitable in conditions of weightlessness. On earth they indicate the direction of a local vertical with high precision. In an orbiting space vehicle a pendulum will simply not swing. Conventional gyroscopes are also not reliable as after a period of time they tend to deviate from the initial direction.

One of the most critical moments is the switching on of the braking system for the return to earth. The slightest inaccuracy in carrying out the set programme can cause the vehicle to come down too steeply, so that it will heat too rapidly as it enters the denser layers of the atmosphere. Or, on the other hand, instead of coming down it may go into a higher orbit and there will not be enough fuel to power the retrorockets. The task of the attitude control system is to prevent such a contingency from ever developing.

In the flights of Soviet cosmonauts one of the axes of the orbiting space ship was oriented towards the sun. Signals from optical and gyroscopic sensors were fed into an electronic unit where they were translated into commands for the control system. The vehicle oriented itself in space accordingly and was kept "locked" in position with a high degree of accuracy. Switching on of the attitude control and retrorocket braking systems was carried out by signals from an electronic programming device.

In the cosmonaut's cabin there is a very remarkable instrument, a small globe representing the earth on which the cosmonaut can see his position above the earth at any given instant.

He can also determine where his vehicle would land if the retrorockets were fired at that moment.

THE SPINNING TOP

To find the way on earth one must establish the directions of North and South. In outer space the points of "up" and "down" must also be determined. As there is no gravity, it is impossible to tell if one is upside-down or not.

Cosmic distances are tremendous, and it is as hard to "hit" a planet with a rocket as it is to hit a pea a mile away with a rifle bullet. In flight it is necessary to have the vehicle stabilized reliably so that the rockets or antennae are always pointed in one direction, say the sun.

This is achieved with the help of sensitive gyroscopic devices the fundamental element of which is a rapidly spinning top universally mounted, i.e., mounted in such a manner that it is free to turn about any axis. A spinning top possesses a remarkable quality; its axis of rotation always strives to maintain a constant orientation in space. This is what makes a toy top stand on end while it is turning. Moreover, if you try to push it over it promptly bobs upright again.

For practical applications gyroscopes may vary in size and weight from several ounces to many tons (gyrostabilizers for ships, for example). There are also natural gyroscopes, like the earth or an electron. The properties of the gyroscope are utilized in a variety of instruments.

It is difficult for an astronaut to control a rocket flying at high speed. This is also true of an aircraft pilot, and so he has an automatic pilot at his disposal. This is a complex instrument that is very sensitive to deviations from a given course. If the aeroplane loses altitude in an air pocket or veers off course, the sensor elements of the automatic pilot send command signals to the rudders, which steer the plane back. The automatic pilot frees the human pilot from the need to watch continuously over the course and altitude, and also frees the mechanisms from the loads developed in manual control.

One of the basic gyroscopic devices is the gyrocompass. It consists of a gyroscope mounted in gimbals in such a way that its axis remains parallel to the geographic meridian. A needle connected with the gyroscope mounting indicates the direction, and the pilot steers by it. A gyroscope may be oriented according to the sun, if necessary.

Gyroscopes are very sensitive instruments, and one perched on a float can show the angular velocity with which the earth is travelling round its axis.

A heavy gyroscope or flywheel can also be used for storing energy.

MAN IS THE MASTER

Today we are used to automation. There are automatic vending machines, automatic assembly lines at factories, automatic pilots that steer huge passenger air liners. The Vostok space ships, too, were automatically controlled. But the cosmonaut was always ready to assume manual control over the machine. It is a case not of automation replacing man but of automation aiding man. The "cleverest" of automatic devices have their limits, and the human operator must always be ready to give a helping hand.

Throughout orbital flight the cosmonaut keeps a vigilant eye on the instruments. Strangely enough there are not so many in the cabin of a space ship, but each one is as good as several. To the left of the cosmonaut's seat is a control panel, about half the size of a desk, and covered with switches, pushbuttons and signal lights. Next to it is another panel with a transparent plastic cover. It also has an array of switches, buttons and lights. At the pilot's right hand is a lever which he touches only if the command, "Assume manual control!" comes from earth. The manual control stick is for steering; when it is pushed to the right the hull turns to the right, and when pushed to the left the ship turns to the left.

The pilot presses a button and a light signal flashes on: "Manual orientation." A white triangle starts running round the rim of the clock face, counting down the firing time of the retro-rockets. Meanwhile the pilot orientates the ship. First he must turn it so that the earth appears in a special view-finding porthole in which a system of mirrors enables him to scan over a range of 2,000 kilometres. From his altitude of 300 kilometres the cosmonaut can see many things.

At last the earth appears in the view-finder. In a few moments the orientation procedure will be completed. But the earth again disappears from the porthole. Meanwhile the white triangle on the clock has reached a glowing amber slit and snuffed it out. This means that the next command signal has been issued to the retro-rocket unit. When the third command is made the descent can be begun.

The pilot shifts the control stick far to the right and then pulls it back. The earth drifts into the view-finder. Less than one minute remains before the final command to the retro-rockets is issued. The white triangle on the clock is rapidly approaching the thin glowing red line. Fire! The cosmonaut pushes a red button. The retrorockets roar to life. The space ship slows down, leaves its orbit and curves towards the earth. As it enters the dense layers of the atmosphere its shell glows a cherry red, and flames flicker on the cabin walls through the blinds of the portholes. Several minutes later the vehicle comes to rest on solid ground.

KEEPING IN TOUCH

They say that when one ancient Greek had to embark on a sea voyage he insisted on keeping in touch with his native land. He tied one end of a ball of string to a column of his house and let the spool unwind as the ship sailed away.

Nowadays travellers in space ships do much the same. Only the home end of their "string" includes huge aerials, covering several thousand square feet, to catch the weak signal from outer space, amplifiers to make it stronger, transformers to extract the message from the signal and, of course, a transmitter. The other "end" is in the rocket racing away with cosmic speed, with its transmitting and receiving radio stations.

The three basic requirements of space communication systems are power, sensitivity and noiselessness.

Power, so that the signal can span vast distances without disappearing altogether.

Sensitivity, as the weight, dimensions and, consequently, power of the space ship transmitter are, for obvious reasons, restricted. Supersensitive receivers on earth pick up and amplify the signal, which may be a million times weaker by the time it has reached the earth.

Noiselessness means the lowest possible level of internal noise in which the weak signals from outer space could easily get lost. Internal noise is reduced with the help of quantum-mechanical amplifiers operating at super-low temperatures of around —250°C, and other low-noise devices.

When the Greek's string broke he could choose between returning home or continuing his journey without the flimsy contact with his homeland. Neither was serious.

A breakdown of the transmitter or receiver in a space ship means the loss of two-way communication; breakdown of both at once is a calamity. Space ships are therefore provided with stand-by equipment ready to take over in case of emergency. This, of course, adds weight to the payload, but so far there is no other way out.

SPACE COMMUNICATION

The heroes of Ivan Efremov's science-fiction novel "Andromeda" sent radio messages home to earth only in the greatest emergencies, so great was the expenditure of energy and so remote the chances of success.

Space communication is a difficult job, for distances are measured in at least hundreds of thousands and millions of miles. The greater the distances the greater the difficulties, and the larger the amount of technical hardware and the number of people needed to service it.

Even the frequency of electromagnetic oscillations used to carry messages between earth and space must be greater.

Space vehicles are linked with earth-based measuring and control complexes by many communication channels. Some are used to carry information about the operation of the rocket systems and the condition of the astronauts, some carry television images of the astronauts, some are for short telegraphic reports, some for telephone conversations, and some for radio programmes. When two or more space ships are in flight at the same time a channel is provided for communication between them.

Communications with a rocket in flight are maintained on a round-the-clock basis. Powerful transmitters send out radio signals to sensitive receivers. The carrier frequency must be chosen very carefully so that the signals do not get lost in the expanses of the universe. Today the basic frequency range for space communication is several tens of megacycles per second.

Andrian Nikolayev, for example, broadcast on 20.006 and 143.625 megacycles, and his space ship also had a 19.995 megacycles transmitter. The earth's ionosphere is almost completely transparent to these wavebands.

In recent years people have been discussing the possibility of using the optical region of the electromagnetic spectrum for space communication. Of course, this does not mean using flashlights, or even searchlights, for blinking messages in Morse code. By making use of the ability of some atoms to emit monochromatic light it is possible to produce a very thin beam capable of spanning millions of miles. The beam could be used as an interference-free message carrier. Optical communication undoubtedly has a great future.

When radio communications are interrupted on earth it is, of course, a nuisance but there are many ways of restoring communication by using other radio channels.

In space this is harder. As a rule the cause of the interruption remains unknown, as the signal of the breakdown is transmitted along the same channels.

A silent space rocket, manned or unmanned, continues on its course. But it is lost irretrievably to those who have dispatched it.

OMNIA MEA MECUM PORTO*

Earthmen are a refined species. In order to breathe they need oxygen, preferably with a concentration of 20 per cent. They cannot get along without carbon dioxide either. Room temperature should be 15 to 25 degrees Celsius. Some people like it cooler and others warmer, but not too much. Atmospheric pressure should be in the region of 760 millimetres of mercury. Finally, humidity should be not less than 30 and not more than 70 per cent. In short, earthmen are spoilt by the atmosphere in which they live. Life as we know would be impossible without its indulgence.

Outer space, on the other hand, is hostile and inhospitable. It is eternally cold. There is neither oxygen nor carbon dioxide. Pressure is nonexistent. And there is no moisture. A man venturing unprotected into outer space would either boil up and turn into cosmic dust, or he would freeze instantaneously, or the sun would roast him to ashes.

Yet man is doing his best to penetrate this hostile environment. He takes a tiny bit of the earth's atmosphere with him in his pressurized space capsule. It sounds so simple. You open the hatches on earth, let the air in, close the hatches and take the atmosphere with you. But man breathes; he inhales oxygen and exhales carbon dioxide. The oxygen content would fall below 20 per cent and the carbon dioxide content would rise above 1 per cent; the pilot would begin to suffocate. One could take extra oxygen up, but how much?

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* All my own I carry with me.

The alternative is to install so-called regeneration units in the space ship. They automatically control the air composition. When the oxygen content falls below a certain level the device switches on and chemical reactions begin which form oxygen. If there is too much carbon dioxide, other reagents start reactions which absorb it from the atmosphere.

However, when the time comes for flights lasting many months and years, no stock of chemical reagents will be sufficient. This is when living matter will be of use. Plants also breathe, but they "inhale" carbon dioxide and "exhale" oxygen. Algae are especially active. In addition some of them, notably chlorella, possess remarkable nutrient value. So travellers to other planets may well take algae with them to provide both oxygen for breathing and food for eating.

Besides the breathing problem there is also the heating problem. For in outer space a rocket hull radiates heat, bringing the inside temperature steadily down to way below freezing point. To cope with this contingency the vehicle must be heated and supplied with thermostats, much like the ones in a refrigerator or an electric iron. If the temperature drops below normal the heaters are automatically switched on. When it gets too warm they are switched off. A breakdown in the heat regulators may lead to the air in the cabin getting too warm for comfort. This happened to one of the American astronauts, and the temperature in his capsule rose to 50°C.

Gas content, temperature and pressure must be controlled to provide the right microclimate inside a space vehicle. Today air conditioning in space capsules is adequate for relatively brief flights, and the main considerations to be taken into account are of a technical and biological nature.

ACCIDENTS IN SPACE

If a ship at sea hits a reef water gushes through the rent in the hull and fills the hold.

If a ship in outer space develops a tiny crack in a porthole or in the hull air escapes and the pressure drops. If the crack is large so-called explosive decompression takes place. The men gasp for air, bubbles of water vapour and gas form in the body tissues and the blood froths, spelling imminent death.

Hazardous though they are the high seas allow shipwrecked sailors minutes and sometimes even hours to save themselves. Outer space grants only a few seconds of respite. In these seconds the crew members must get on their oxygen masks or dive into their pressurized suits. A pressurized suit is one of the best ways of combatting explosive decompression in a space ship.

However, other accidents may occur, such as a collision with a small meteoroid. What is to be done in such an emergency, when it is hundreds of thousands or even millions of miles to the nearest rocket servicing station? Besides, a station in outer space would never be a stationary station, and in any case the building of such stations is still a task for the future. Flights to the moon will certainly be undertaken before the first servicing station in outer space is built. What measures, then, should be taken to save the crew in an emergency? Here is one suggested rescue scheme for a moon flight.

The first dangers lie in wait for the astronaut on the launching pad. For example, the fuel of the carrier rocket may explode. To save the space capsule from being destroyed by the blast it must be ejected hundreds of feet away in a fraction of a second. The acceleration load may be 20 times that of the acceleration due to gravity, but with the astronaut strapped to a suitably designed seat it can be withstood for the brief period it lasts without detriment to the health.

The stage following blast-off and the initial climb is flight through the upper layers of the atmosphere. If there is an accident at this stage the capsule must be returned to earth.

But then there is the danger of overheating on entering the denser layers. This danger is coped with by the ejector motors shooting the capsule out perpendicular to the flight path, so that it enters the atmosphere along a smoother curve.

If an accident happens in the coasting stage of the flight from the earth to the moon the rocket is blasted into an elliptical trajectory that takes it back to earth by the shortest way. Such a manoeuvre, of course, requires fuel, so it is taken from the rocket stages that would have ensured a soft landing on and take-off from the moon.

But having successfully covered 384,000 kilometres the rocket approaches the moon and enters into a so-called parking orbit around it. The crew choose a suitable place for landing and direct the rocket downwards. Here, too, something may go wrong, and now there is very little fuel left in the tanks. In this case the take-off rocket stage is fired, and the rocket returns to the parking orbit, from where it can fly back to earth.

Obviously it would be much simpler to repair a rocket that has had an accident in the neighbourhood of the moon on the moon itself, instead of shuttling it back to earth. But this will only come when a trip to the moon is as common as a drive out of town.

CUSTOM-BUILT

We are so used to living at the bottom of our atmosphere that it is hard to imagine that it presses on us with a force of one kilogram for every square centimetre of the body. This is because our bodies are well adapted to the pressure. At high altitudes the pressure is much less, and above 10 kilometres an oxygen mask alone is not enough.

When we breathe our lungs expand and contract. On earth this is accomplished easily enough by the muscles of the chest and abdomen. But high up above the earth the external pressure is low while the body pressure is maintained by the continuous supply of oxygen. As a result the muscles are unable to contract the chest. They must be helped by compensating for the shortage of atmospheric pressure.

Man ventures out into space in a pressurized capsule. There it is simple, as the required pressure is maintained by the continued supply of breathing air. But what happens if the pumps break down or a leak develops?

For such an emergency a partial-pressure suit is provided. This is a tight-fitting union suit made of linen, cotton or nylon cloth and worn over thin silk underwear. It is tightly fitted to the body by lacing along the sleeves, legs and back. The outside of the suit is criss-crossed with rubber tubes held in place by cord loops.

If the pressure in the capsule falls an automatic valve opens and allows air to flow into the rubber tubes. They expand and thus tighten the suit, supplying a substitute pressure round the pilot's body. He can normally inhale the oxygen supplied under his helmet.

In some partial-pressure suits rubber bladders rather than tubes are sewn into the chest part of the suit. When they expand they provide a more evenly distributed pressure over the whole of the chest.

Obviously, a partial-pressure suit cannot replace a pressurized cabin. It is merely a safety measure in case of an emergency, but it has proved its worth.

THE PRESSURIZED SPACE SUIT

So far all Soviet cosmonauts, with the exception of the three-man crew of Komarov, Feoktistov and Yegorov, have made their flights in special space suits. This is to afford additional protection. A space suit is in fact a capsule within the space ship capsule (as far as protection is concerned). It has self-contained systems for oxygen supply, heating, pressurization and radiation protection. It is equipped with microphone and earphones for communication with the earth, and also sensor elements which tell the people on earth how the astronaut is feeling.

An astronaut can land on earth inside the capsule or he can be ejected in his space suit. Scientists and engineers are, of course, looking forward to spacecraft provided with saloons, libraries, gymnasiums and dining rooms, all so reliably protected that there will be no need for space suits, except for jaunts outside the vehicle —whether en route to the moon and other worlds or on those worlds themselves.

THE EJECTION SEAT

The parachute as a means of escape from a crippled aeroplane is almost as old as the aeroplane itself.

However, in these days of highspeed aircraft it is very difficult, if not impossible, for the pilot to bail out. The high velocity of the air stream may hurl him with tremendous force against the body or structures of the aircraft. So nowadays a pilot, instead of bailing out in an emergency, is literally blown out of the aeroplane together with his seat.

The seat, or in some aircraft the cabin or cockpit as a whole, is slid into the aircraft structure along rails. Attached to it are three parachutes—small, medium and large.

When the time for ejection comes (in an aircraft this is always an emergency, while in a space vehicle it may be standard landing procedure), the pilot draws down the visor of his helmet and throws a lever.

Special grips pin his feet to the footrest of the seat, and side shields slide out to protect his arms.

The flight oxygen supply is switched off and an emergency unit built into the seat takes over.

The transparent cockpit canopy is drawn back, the ejection cartridge fires and the seat or capsule is hurled clear of the craft.

At once the first, small, parachute opens. Its purpose is to stabilize the seat or capsule and keep it from tumbling in the air. After that, an automatic barometric device opens the second, braking, parachute at a preset altitude. Finally, when the pilot has dropped below 3 kilometres and can take off his oxygen mask or helmet the last parachute opens. The pilot separates from the seat or capsule and lands like an ordinary parachute jumper.

THE SCYLLA AND CHARYBDIS OF OUTER SPACE

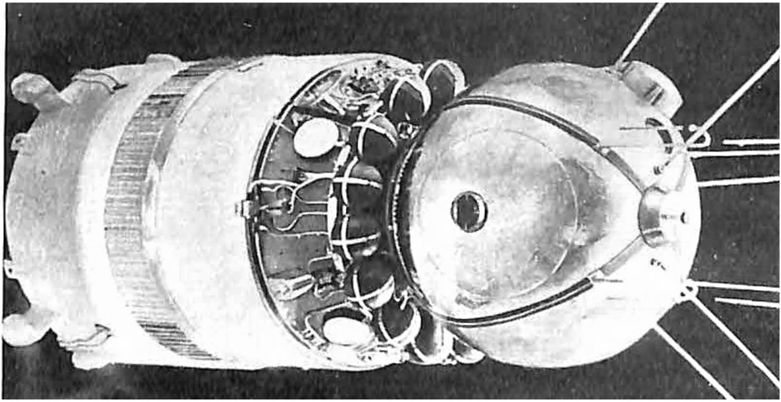
Odysseus' homeward journey was certainly not a pleasure jaunt. The Argonauts were tempted by sirens and pursued by man-eating cyclopes. Other obstacles in their way were two rocks within a bowshot of each other. Under one dwelt Charybdis, the whirlpool which sucked down everything that came near. In a cave in the other rock lurked the dreadful sea monster Scylla who devoured every living thing that passed within reach.

The Odysseuses of outer space have to pass through similar trials on their homeward trip. G-loading and heating are the Scylla and Charybdis of the cosmic ocean. A steep descent into the atmosphere can develop loads sufficient to crush the fragile bodies of men. On the other hand, skimming in at a tangent can drag out descent and increase the hazard of overheating the capsule and burning it up. As we know, Odysseus was able to manoeuvre between the twin rocks by sacrificing six of his men. A space ship has to sacrifice its skin.

When the retrorockets are fired in preparation for the descent to earth, the astronauts must steer their space ship into the atmosphere at an optimum angle. This angle must be neither too steep nor too sloping if they are to keep themselves from being either crushed by their own weight or roasted alive. The ceramic coating of the hull bears the brunt of the thermal shock produced by the onrushing atmosphere; it melts and thus saves the vessel. The coating

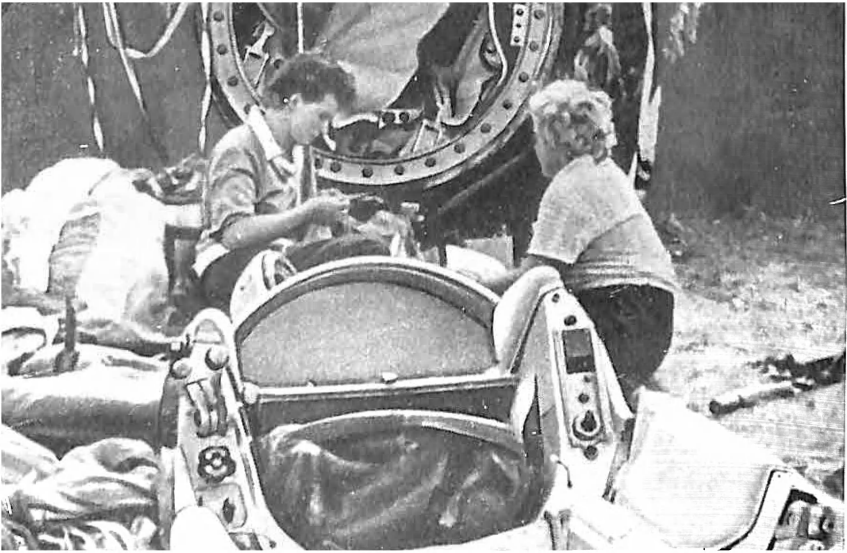
Sergey Korolyov, Chief Space Ship Designer, and Yuri Gagarin, first cosmonaut

The sparkling sphere of the Vostok carried the first man into space



The Vostok capsule before launching

Valentina Tereshkova, commander of the Vostok-6, has just touched down



lasts just long enough for the capsule to come down low enough, at a sufficiently low speed. A parachute opens and lowers the capsule gently onto solid ground, as is done in the Soviet Union, or into the ocean, as the Americans prefer. Soviet cosmonauts can also opt for leaving the capsule and descending with conventional parachutes.

JUST IN CASE

"Shipwrecked brother, if you have faith and hope you will find that your wealth will multiply from day to day, as Robinson Crusoe's did, and you will have no reason for giving up hope of being saved." These words conclude a book written by Alen Bombard, who crossed the Atlantic alone in a small boat without once touching his emergency food stock.

On earth, even when he is alone in the ocean or a desert, man can hope for some gifts from Nature. But what happens when an accident occurs in outer space? What should an astronaut's emergency reserve consist of?

The essential premise is that the astronaut can return to earth in the space capsule in an emergency. But he may land beyond the Arctic Circle, in a desert, or in the ocean. Two-thirds of the earth's surface is covered with water, hence the most likely eventuality is a landing on water and the plight of a shipwrecked sailor.

Food, water, a desalting unit and an inflatable boat are musts in an emergency reserve.

Clothing must be water- and cold-proof. Pneumatic load-absorbing devices will buoy the astronaut up at first. Add a radio transmitter-receiver, and a "shipwrecked" astronaut will be better off than Alen Bombard was.

Incidentally, the American astronaut Malcolm S. Carpenter dipped into his emergency reserve. It took the rescue crew more than two hours to locate him, and when they came they found him on an inflated raft.

17 NIGHTS IN 25 HOURS

History is a mysterious wheel which no one can hope to turn back. Moreover, it seems to be turning faster and faster. Art styles come and go. Men's lives and their attitude towards life change. Speeds increase. The first artificial satellite of the earth, launched on October 4, 1957, circumnavigated the globe in 96 minutes 9 seconds.

As long as the atmosphere does not affect the motion of a satellite it travels in a closed circular or elliptical orbit. The satellite's position is noted with respect to the fixed stars. Then a note is made of how long it takes to return to the same spot after circling the earth. This is its period of revolution. It is also called the sidereal period. A man on the pole can easily measure the sidereal period, provided that he turns in the direction opposite to the earth's rotation with the same speed. For then he will be motionless with respect to the stars.

Now imagine an observer on the equator tracking a satellite moving from west to east in the plane of the equator.

In the time it takes the satellite to make a complete circle of the heavens the earth will have carried the observer forward and the satellite will appear in the zenith a little later. The time between two identical positions of an equatorial satellite is called the synodic period.

If the earth had no atmosphere a satellite skimming just over the surface in a circular orbit would have a sidereal period of 88 minutes 25 seconds. This is the shortest possible period for a satellite of the earth. The greater the radius of a circular orbit the smaller the earth's gravitational pull, the slower the satellite travels, and the longer its path. At an altitude of 265 kilometres a satellite takes an hour and a half to circle the earth. The moon takes about four weeks.

Can the radius of a satellite orbit be chosen so that its sidereal period equals 24 hours? Such a satellite would hover constantly in the sky over the same point of the equator, that is, its synodic period would be infinite. The satellite, we find, must be launched to an altitude of 35,800 kilometres above the equator. It would be very convenient for transmitting television programmes over long distances. Three such satellites would provide a world-wide television network.

If a satellite travels in an elliptical orbit, its period of revolution is determined solely by the semi-major axis.

An interesting aspect of satellite motion is observed when it enters the atmosphere. It would appear that if the atmosphere retards the satellite it should travel more slowly, taking longer to complete a revolution, with a corresponding increase in the period of revolution. Actually, however, the period gets shorter. This paradox is explained simply enough. Maximum retardation of the satellite takes place at its perigee, where the air is denser. As a result, the height of the apogee of the next orbit decreases, and hence the velocity at the apogee increases, for the lower a satellite orbit the faster the satellite travels. Thus the mean velocity increases and the period decreases.

And finally, one period carries a satellite through a day and a night. Titov saw 17 cosmic days and nights in the course of his 25-hour voyage, Nikolayev had 64 in four terrestrial days, and Bykovsky, 81 in 5.

APOGEE AND PERIGEE

In the 2nd century B.C. Hipparchus discovered that the moon appeared to alternately come closer to the earth and then recede from it. Later it was found that the moon travels in an elliptical orbit, with the earth at one of its foci. Like any other ellipse, the lunar orbit has two remarkable points; one farthest from and the other closest to a focus. They are called the apogee, which in Greek means "far from the earth", and the perigee, which means "near the earth". For centuries the apogee and perigee remained the only points of their kind in the universe, and belonged to the moon alone.

Then on October 4, 1957 an artificial satellite went into orbit to rival the moon. Like the moon it travelled in an ellipse, and had an apogee and perigee of its own.

Other satellites were launched with different lifetimes. Obviously the lifetime of satellites moving in circular or nearly circular orbits depends on their altitude above the earth; the higher a satellite the less it is retarded and the longer its lifetime. But what about satellites with elongated orbits? It was hard to say what point affected their lifetime more, the apogee or the perigee. At first it was thought that only the perigee mattered as the atmosphere is denser here and the velocity greatest. Actually the picture of the ageing and death of a satellite is as follows: the apogee begins to descend slowly while the perigee remains almost unchanged. The orbit becomes less elongated and steadily approaches a circle. When the perigee and apogee become equal the satellite spirals into the atmosphere, where it burns up.

ORBITAL INCLINATION

It has been known since Newton's time that the planets move in flat orbits and the planes in which they move are constant. There are nine such planes (not counting the asteroids) and none of them coincide. The plane of the earth's orbit is called the plane of the ecliptic, and all the other planes are inclined to it at various angles. The orbital plane with the greatest inclination to the ecliptic is that of Pluto, with a value of 17°.

Artificial satellites and space ships also have orbits. They revolve around the earth and it would therefore be inconvenient to measure their inclinations with regard to the ecliptic. The plane of the equator is more suitable. Hence the orbit of an equatorial satellite is inclined at zero degrees, and that of a polar satellite at 90°.

Many Soviet satellites are launched with an inclination of 65°; this was also true of the Vostok series of space ships. The reason is that with this inclination the satellite or space ship stays over the Soviet Union for the longest possible period.

The apparent motion of a satellite depends on the inclination of its orbit to the equator. When plotted on a map of the globe, it has the appearance of a sinusoidal curve, with crests and troughs.

This is because, although the plane of a satellite's orbit is motionless, the earth is turning. At every given instant a satellite's position is projected onto the surface of the earth along the radius to the centre. These points are plotted on a map, yielding the sinusoidal curve. The curve for an equatorial satellite will be a straight line, satellites with inclined orbits will trace curves that do not reach up to the poles, and only a polar satellite will sweep over the whole surface of the earth.

AN ARTIFICIAL COMET

A space rocket 100,000 kilometres away would look like a star of the 14th magnitude, meaning that it would shed 1,600 times less light than a 6th magnitude star, which is the limit visible to the naked eye. But there is a way of increasing the brightness of a rocket temporarily, and the idea was taken from Nature. It is known that the gaseous tails of comets glow brightly in the rays of the sun despite their extreme tenuity. So it was suggested that an artificial comet could be made by ejecting a cloud of atomic sodium. As a result of the effect known as resonance fluorescence, the cloud of sodium would cause an intensive scattering of the yellow component of sunlight. Preliminary experiments and calculations revealed that a sodium cloud produced by one kilogram of sodium would appear as a star of the 6th magnitude at a distance of 100,000 km.

At 3 hours 56 minutes 20 seconds Moscow time, on January 3, 1959, when Luna-1 was 113,000 km from the earth, a special device set fire to a mixture called thermit, and sodium vapour was ejected from the rocket in a cloud some 100 kilometres miles in diameter. Many tracking stations in the Soviet Union sighted the cloud and photographed it. Two minutes later it had dispersed and disappeared from sight. The short-lived comet enabled the scientists to verify the rocket's position with great accuracy.

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To the wonderful shores
Of new lands and far away stars
We shall come with simple hearts,
With spades and wise books.

PABLO NERUDA

TO DISTANT PLANETS

The urge to travel has always been one of the important factors contributing to human progress. From time immemorial men have attacked the boundaries of the unknown. The time came when the first man flew up into the air, and now he has penetrated beyond the atmosphere.

Earthmen of the thirtieth century will doubtless view the clumsy space vehicles of the 20th century with a condescending smile. "How clumsy and inefficient," they will say. But then they may pause to reflect that these were the vehicles which made the first breakthrough into space. They will look at them with new eyes, much as today we view the caravels of Columbus, and as Columbus' contemporaries must have regarded ancient galleys.

Passenger rockets for interplanetary flight are yet to be built, but the scientists have already charted routes for them.

After passing through the atmosphere a rocket veers round and accelerates in an ascending spiral. When it attains the escape velocity it breaks away from the earth's gravitational pull and becomes an attendant of the sun, moving in a vast elliptical orbit through interplanetary space. Somewhere in the void, according to the scientists' calculations, the rocket's path will intersect the orbit of Venus, Mars, Mercury or some other planet. The point is known with great accuracy, but it takes months to reach it. The first travellers to Mars will spend a year in flight. A trip to Venus will take about a hundred days. How will the Columbuses of outer space stand up to the stresses of prolonged space travel? Some answers to this question are known.

The space flights carried out so far, tests in sealed cabin simulators, prolonged space-food diets and other tests indicate that the first interplanetary travellers will feel well. The only unknown quantity is the effect of many months of weightlessness. Apparently scientists and engineers will have to consider artificial gravity.

Meteoroids, the rocks of outer space, are a major hazard. Big lumps are very rare and most meteoric bodies are specks of dust weighing less than a milligram, but even so, considering the tremendous speeds of outer space, they are dangerous.

But the day will come when all the hazards have been left behind and the rocket approaches a strange planet. The travellers will not be in a hurry to land and will place their ship in a satellite orbit. Later on they may go down in small landing craft. What will they find on the new world? Strange mountains, deserts and oceans and, of course, unknown perils. But what exciting perils!

NUCLEAR PROPULSION

One of Konstantin Tsiolkovsky's greatest concerns was that of finding a fuel that could carry a vast amount of energy in the smallest possible volume. Modern rocket propellants, whether solid or liquid, still fall far short of the ideal.

To attain the velocities needed to escape the gravitational pull of the earth and, which is even more difficult, of the sun, several rockets must be hitched together. Each stage is in effect nothing but a fuel tank.

If a fuel could be found with a great store of energy packed away in a small volume there would be no need for multistage rockets. There would be no need either for orbital refuelling stations.

The inference is obvious; nuclear fuel.

The new age of science began with an "autographic" record left on a photographic plate by invisible uranium radiation. Today the atomic nucleus, which is still only partly tamed, has invaded many fields of science and technology. Nuclear power is transformed into electricity, and drives ships and submarines. It cannot yet carry a rocket up into outer space. The obstacle is invisible but real enough; gamma radiation.

Nuclear reactors at electric power plants are shielded with concrete walls several feet thick to protect personnel from this penetrating radiation. The shielding is cumbersome and heavy and there is no way of carrying such a shield aloft, even given the boons of weightlessness.

There are plans for nuclear powered space ships, however. According to one of them, the vehicle would have several compartments. At the front are the flight controls and crew's quarters, amidships are tanks of hydrogen, a fuel with a very high thermal conductivity, and aft is the nuclear reactor.

The hydrogen is designed to replace the concrete shield of the earth-based nuclear plant and to protect the crew and passengers from radiation. The heat produced in the reactor heats the hydrogen and fiery jets from the rocket's nozzles drive the vehicle forward.

The design is simple enough, but there is one major stumbling block; the temperature of the gaseous jet must be about 10,000 degrees Celsius. The temperature in the nuclear reactor heating the hydrogen must be still higher.

Nevertheless, it will surely not be too long before nuclear propelled spacecraft exist not only in science fiction but in real life as well.

ISOTOPE MOTORS

Today any school leaver knows (or should know) that isotopes are atoms of the same element with different atomic weights and equal charges. A school chemistry textbook will also tell us that, starting with element number 83 in Mendeleyev's Periodic Table, every square in the table is occupied by isotopes of radioactive elements which decay spontaneously. Nowadays hundreds of thousands of people deal daily with isotopes in one way or another. In Moscow there is even a special shop dealing in isotopes. It is hardly surprising, therefore, that isotopes have been suggested as a fuel for space rockets.

Such a motor would produce neither fire nor smoke. The thrust would be created by the exhaust of radioactive decay products; alpha-particles, which are nuclei of helium, beta-particles, which are electrons, and gamma radiation. The most efficient of these are the alpha-particles, which are heavy and exert a thrust almost 10,000 times greater than the electrons. The thrust produced by gamma radiation is negligible.

For this reason two British scientists chose as a propellant for their space vehicle an isotope of thorium with an atomic weight of 228, which decays with the emission of alpha-particles. Another valuable property of this isotope is that its half-life (the time taken for half of a stock of thorium-228 to decay) is 22 months. This means that for the duration of a flight the radiation flux will be sufficiently powerful and stable.

A thorium disk some 12 metres in diameter would yield a flux of particles sufficient to drive a rocket to Mars. To be sure, the thrust of such a propulsion system is measured in grams, as compared with hundreds of thousands of tons for liquid-propellant rocket motors. But an isotope motor would be working all the way to the rocket's destination while a "conventional" rocket motor burns out in a matter of minutes. Added to this, the velocity of the exhaust of an isotope motor is three or four thousand times greater.

But if a thorium disk is to be used as a motor one important operation must be carried out. Alpha-particles are naturally expelled in all directions, but a thrust is developed only when the sum-total of all complex or simple, prolonged or instantaneous processes yields a flux of alpha-particles in one direction. This is elementary mechanics. Therefore a beryllium absorber must be attached to one side of the thorium disk to catch all the forward-moving alpha-particles.

The design of an isotope-propelled rocket is simple enough. It consists of the crew's quarters, the beryllium absorbent layer and the thorium source. It satisfies all the requirements of simplicity, lightness and reliability. The only drawback is that, unaided, the rocket cannot take off from the earth. So a liquid-propellant rocket will have to be used to carry it beyond the earth's gravity, from where it can continue on its own.

The lightness and reliability of isotope motors make them invaluable for artificial satellites. They can function for long periods of time and they are not readily damaged by meteors; even if a chunk is torn out of the disk it will continue to function.

WHAT ABOUT PLASMA?

Plasma is known as the fourth state of matter. It differs from the solid, liquid and gaseous states in that the atoms of plasma are stripped of their electrons, which are free to travel on their own. As the positive charges of the atomic nuclei and the negative charges of the electrons are balanced a plasma is electrically neutral. Plasma may be cold or hot. Physicists exploring the ways of producing controlled thermonuclear reactions work with plasma at millions of degrees. The designers of space ship motors are content with "cold" plasma of 3,500-10,000 degrees Celsius. Incidentally, you encounter this kind of plasma more often than you may realize. For example, the beam of light on a cinema screen is produced by a plasma column between two carbon electrodes in the film projector.

Powerful electric arcs yield temperatures higher than in any chemical reaction. If a gaseous working substance is heated in the flame of such an arc and expelled through the nozzle of a propulsion unit, exhaust velocities of 15-20 kilometres per second can be obtained, which is five times faster than the exhaust in the best chemical rockets. Moreover, it is much easier to control the jet of such an electric arc or electroplasmic motor.

Exhaust velocities of up to 100 kilometres per second can be obtained in electromagnetic plasma motors. To do this the designers exploit the fact that plasma is an excellent conductor of electricity. It is well known that a conductor carrying electric current is accelerated in a magnetic field; this is the principle on which all electric motors work. Accordingly, if plasma is placed in a magnetic field and an electric current passed through it, everything then takes place according to the "left-hand rule" of school physics.

A rocket equipped with such a motor would require a considerable supply of electric power; about 100 kilowatts per kilogram of thrust. This poses the problem of electricity generation. Small nuclear reactors could evidently be used, sunlight could be focussed by mirrors and made to convert water into steam to drive a turbine generator, or photoelectric cells or thermoelectric cells could be used.

The prospect of using such rockets for space travel is a promising one. They require much less fuel than chemical rockets, and therefore they will weigh less and can travel further. Like isotope (and ion) rockets, however, they would have to be lifted from the earth by chemical rockets, or they could be assembled at orbiting satellite stations in space.

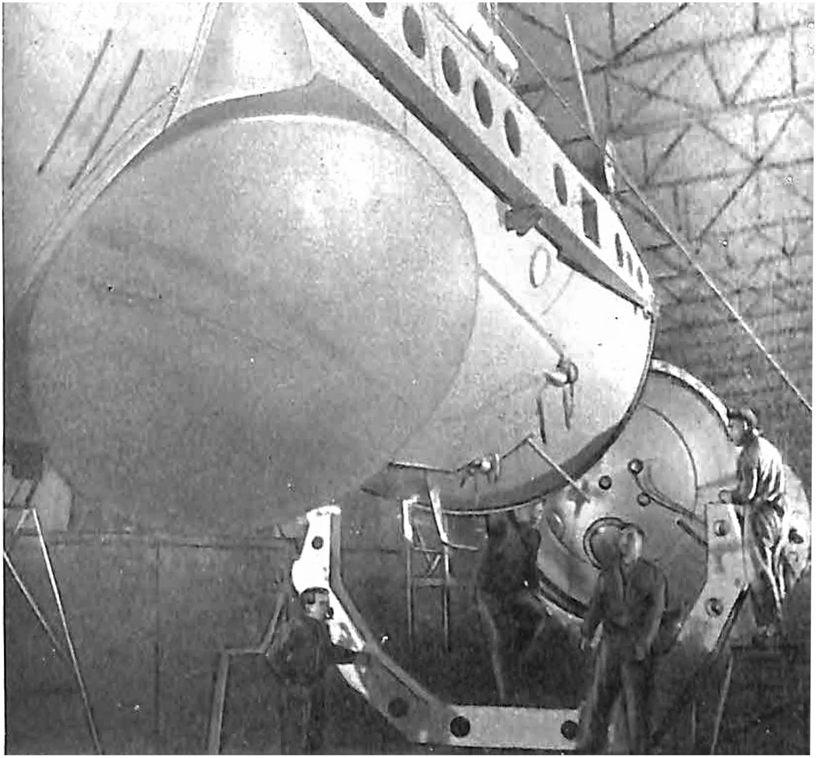
ION PROPULSION

Another possibility which scientists and engineers are considering is the ion rocket. Any rocket is propelled by the recoil from the ejection of the products of fuel combustion. It does not matter whether a lot of this working substance is ejected at low speed or a little at high speed; the effect is the same. The engineers therefore do everything they can to increase the exhaust velocity of the gases, so that less fuel is required and the payload can be increased. Chemical rockets have almost reached the limit in this respect, and an exhaust velocity of several miles per second is all they can yield.

An ion rocket could provide exhaust velocities limited only by the speed of light, which is the greatest velocity with which any material body can ever move. So a physicist would not be surprised at the idea of converting a particle accelerator into a rocket motor.

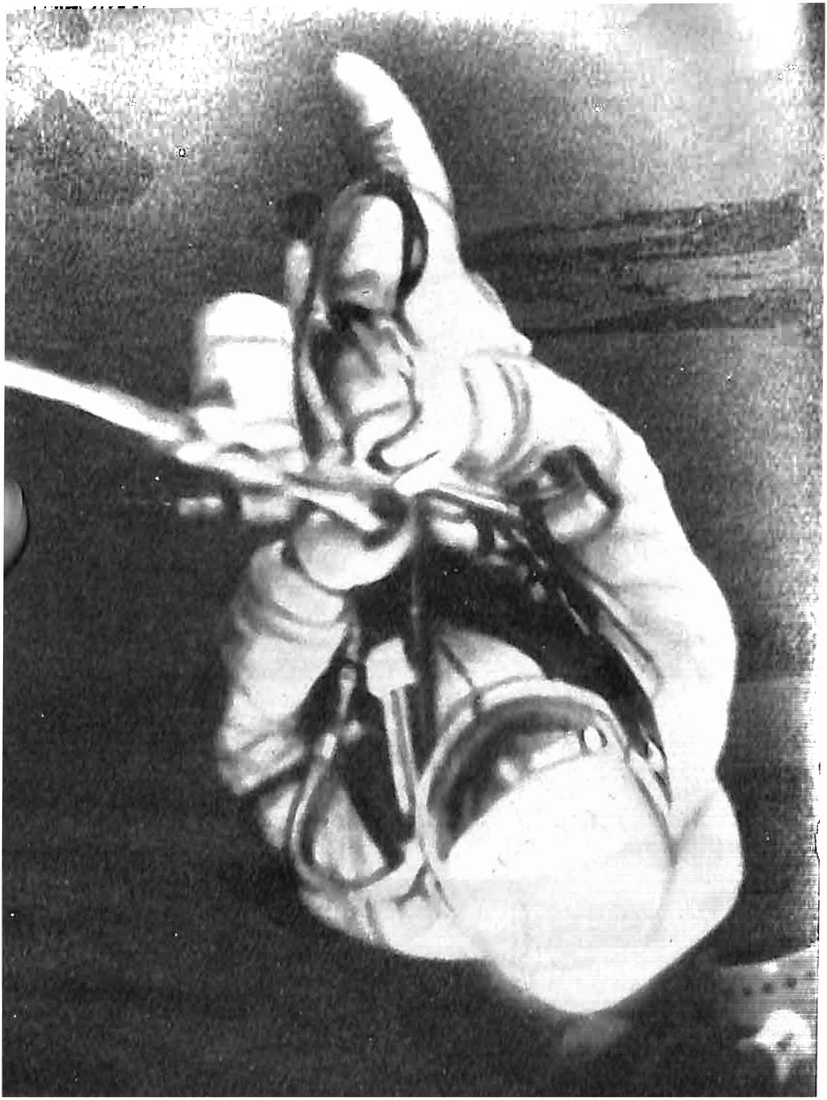
The principle is simple enough. Either a small nuclear reactor or semiconductor solar batteries are used to generate electricity which in turn produces and accelerates charged particles. Caesium or rubidium vapour is used in the ionization chamber. These rather rare elements are chosen as ion "fuel" for two reasons: their ions are heavy and they ionize easily (their atoms easily yield the single electron in the outer electron shell and they become positively charged ions).

An electric field generated by circular electrodes continuously draws the ion cloud into a narrow beam and directs it towards the accelerator electrodes. The accelerated ions are then ejected through the nozzle into outer space. But at this stage the electrons that were originally removed from the atoms must be returned, or else the motor will be stopped up by the electric



The Voskhod-2 being prepared for a spaceshot

Soon one of them will take a walk in space



Alexey Leonov on his extravehicular excursion field of the ion trail. For like charges repel one another, and the first batch of ejected ions would push back the ones following. Therefore the ion flux is neutralized at the exit by injecting electrons.

This can be done by placing a tungsten grid in the path of the beam and heating it electrically. Electrons will evaporate from the hot surface and mix with the ions, or the electrons stripped from the atoms can be returned.

There can be no doubt that the future of ion motors is promising. Small motors weighing not more than 30-70 kilograms will be used in satellites for attitude control and orbit transfer. In flights to neighbouring planets ion rockets can be used for shipping freight.

Meanwhile ion motors are being tested. The first such test in outer space was carried out in the attitude control system of a Voskhod space ship in 1964.

ANTIMATTER

There are innumerable obstacles blocking man's way into outer space, ranging from the earth's gravity and G-loading to weightlessness and radiation. Yet people continue to dream of flying to the stars, although stellar flight imposes even more restrictions. The main ones are the theoretical impossibility of accelerating a space vehicle to speeds faster than the speed of light and the brevity of human life.

The genius of Einstein pointed out a way of minimizing the latter restriction. According to his theory of relativity (and these days even its most bitter opponents have been converted) the higher the velocity of a rocket the slower the passage of time in it, as measured by a terrestrial clock. It is therefore conceivable that a journey that would take 100 years according to a terrestrial clock would last an hour for the crew of a rocket travelling at almost the speed of light.

It follows, then, that the question is not so much one of the short span of human life as of the low speeds of modern rockets. And this follows from the inefficiency of chemical fuels. It has been calculated that to accelerate a one-ton rocket to the speed of light 1,000,000,000 tons of the best chemical propellants would be required.

This leaves the main obstacle in the way to the remote stars: fuel. Scientists are considering many diverse propulsion systems, from lasers and solar sails to nuclear propellants and photon rockets.

One of the enthusiasts of new types of rocket propellants is Bruno M. Pontecorvo, of the U.S.S.R. Academy of Sciences, one of the discoverers of the neutrino and mysterious electron- and meson-like particles. According to Pontecorvo, neutrinos and antineutrinos may be messengers from other worlds which may one day open up their mysteries to us.

A natural development of the discovery of antiparticles is the question of whether it would be possible at some date to produce antimatter and make use of its energy of annihilation for space flight? It is estimated that three and a half tons or so of antimatter could take a rocket to the distant stars. But how much is three and a half tons of antimatter? A lot or a little?

Various elementary bricks of antimatter have been discovered: anti-electrons, antiprotons, antineutrinos. But such small quantities have been found that it would take hundreds of years of miserly hoarding to collect three and a half tons of antimatter. But even before the problem of producing antimatter has been solved there is the problem of storing it. For how is one to keep it from coming into contact with ordinary matter and annihilating it with a big bang?

LOST ILLUSIONS

Will earthmen ever see the mysterious worlds of the distant stars? Will a propulsion system capable of carrying man beyond the solar system ever be created?

Yes, the optimists say. We don't know when, but one day men will visit the neighbourhood of Alpha Centauri. "What is impossible today will become possible tomorrow." The enthusiasts of interstellar flight like to repeat these words of Konstantin Tsiolkovsky. And they put forward many original ideas to support their belief.

The advocates of photon motors, photon rockets and photon space ships are especially vociferous. What have they to suggest?

Every rocket is propelled by the "recoil" of a jet escaping from a nozzle with high speed. The photon rocket would be propelled by the recoil of a powerful flux of electromagnetic radiation quanta, photons as they are called or, simpler still, light. The fundamental advantage of using light as a propellant is that its exhaust velocity is 300,000 kilometres per second, the highest that can ever be obtained. Thus a photon rocket could conceivably be accelerated to almost the speed of light. Therein lies the attraction of photon propulsion in the eyes of enthusiasts. For only if such speeds are attained can the Einstein time dilation be exploited to carry men from the earth to a star in a lifetime.

Many schemes have been developed from this basic principle. For example, photons are generated in the mutual annihilation of electrons and their antiparticles, positrons, in which matter changes into gamma radiation. It has been suggested that a plasma torch be kindled astern to generate light at a temperature of 150,000 degrees, or that a controlled thermonuclear reaction be used. Photon fans are wont to let their imagination run away with them, but the sceptic is quick to come on the scene.

"Well," he says, "and what if you were to attain such speeds?"

"Many interesting phenomena would occur," the photon fans declare. "Stars, for instance, would alter in appearance. Yellow stars astern would get redder as the speed increases. (Owing to the Doppler effect bright rays shift towards the red end of the spectrum.) They would turn into red lights and then go out all at the same time. On the other hand, the stars directly ahead would become violet, and infrared stars, which cannot be seen by a 'resting' observer, would become visible."

"But what about the meteor hazard?" the sceptic says.

"We will set up a shield to ward off small particles. We will dispose of the bigger ones with the help of ray guns."

"For your information," the sceptic persists, "a particle with a mass of one milligram and an impact velocity of 0.866 the speed of light can vaporize 10 tons of iron. No shield can offer sufficient protection."

"We will make an electric shield. We will ionize particles and deflect them by means of magnetic fields."

"Don't forget that besides dust outer space contains hydrogen, one atom to every cubic centimetre. At velocities approaching the speed of light protons will pierce your photon ship and its crew like paper at the rate of 10^{10} particles per square centimetre of surface area, which is 10^{10} times the density of cosmic radiation on earth. It would be like living in the working chamber of a powerful proton accelerator. Your photon ship will be a death ship!"

"Not at all. Protons can also be deflected by magnetic fields and suitable shields will be devised."

But at this point the sceptic reaches for his slide rule and delivers the final blow to the photon dream:

"At the velocities required to circumnavigate the Milky Way the ratio of a rocket's initial mass to its useful mass is $10^{17} : 1$. Assuming a useful mass of 100,000 tons, the total mass will be 10^{22} tons. Incidentally, the mass of our little planet is only 6×10^{21} tons."

At this the photon enthusiasts grow sad and retreat, defeated but unconvinced. For no amount of reasoning can quench man's dream of interstellar travel. And even if photon rockets never take off, man will discover new principles which we are at present unable to predict. Science will overcome the interstellar barrier and our descendants will surely see the magic worlds of blue suns.

DUCKS AND DRAKES

The best way of overpowering an enemy is to make him into a friend.

The diaphanous air of the blue sky is an enemy to a space vehicle entering it on the return to earth. It pierces the atmosphere like a meteor and heats up tremendously as it slows down. The vehicle should be prevented from dipping into the dense layers too steeply, and here the air becomes a friend instead of an enemy.

Wings are an old invention. One has but to attach wings to a rocket....

"What do you mean by wings?" the reader might ask. "Can they be of any use at high altitudes? What would they rest on? The air is too rarefied up there."

But the word "too" is relative. An atmosphere that is rarefied for slow movers is quite dense for space vehicles. The important consideration is not the density of the air but the lift force of the wings, and this depends on the velocity pressure, which is the product of the density and the square of the velocity. And so a fast flying rocket can be given wings.

A rocket casts off from the side of a heavy satellite, switches on its retromotors and begins to descend. It enters the denser layers of the atmosphere, but before considerable heating develops the lift force from its delta wings pushes it back up into the "vacuum", and it describes an arc before dipping into the atmosphere again.

Boys like to throw flat stones so that they skip over the surface of water. This game is known as ducks and drakes. Similarly a winged rocket "plays ducks and drakes" in the atmosphere, and gradually slows down and cools. When the velocity has been reduced sufficiently it dives steeply and makes a landing like a conventional high-speed aeroplane.

Soaring rockets still belong to the future, but they should have interesting applications. A winged rocket launched from the earth could travel large distances round the globe in gigantic leaps only slightly reinforced by rocket propulsion. Winged rockets may one day compete with transcontinental supersonic aircraft.

TO VENUS AND MARS

On February 12, 1961, man made his first assault on cosmic distances; he launched an automatic interplanetary space probe to Venus.

The distance to the "morning star" ranges between 300 million and 40 million kilometres. As regards size and mass our neighbour in the solar system is almost the earth's twin, and it has a dense atmosphere. In order to reach it a space vehicle travelling around the sun with the same speed as the earth must be retarded, and then the sun's gravity will pull it down and it will cross the orbit of Venus.

The Venus probe was launched in several stages. First a heavy satellite was placed in orbit round the earth. A space rocket took off from it, and shortly afterwards the probe separated from the rocket and began its journey. The 643.5 kilogram probe resembled a huge butterfly, with wings carrying solar batteries to power the instrumentation pack. Several antennae were used to maintain communication with the earth, and a highly directive parabolic antenna was to be used for transmitting data at the time of the probe's closest approach to Venus.

An automatic attitude control system kept the probe continuously "locked" in space with respect to the earth and the sun. Other automatic systems kept the pressure and temperature constant inside the instrumentation capsule. This was necessary to ensure that the instruments (for measuring cosmic radiation, magnetic field, streams of charged particles, micrometeorites, etc.), radio transmitters and data relaying system functioned reliably.

As long as communications were kept up the probe transmitted important data that contributed to our knowledge of outer space. And even though communications later broke down and we know nothing of the fate of the first Venus probe (some enthusiasts like to think of it falling on Venus and inquisitive Venutians inspecting it with interest and awe), it blazed the trail for the American Mariner-2 and other space probes.

On November 1, 1962, the Soviet Union launched its Mars-1 probe (weight 893.5 kg), which held the record for radio communication (over a distance of 106 million kilometres) until the Soviet Zond-2 and the American Mariner-4 were dispatched on their respective missions to Mars.

MARS SHOWS ITS FACE

Some time in the near future the mysteries of Mars will at long last be solved and we shall know the answers to the exciting questions of whether or not there is life there and what its canals are.

Many scholars declare that living organisms will certainly be found on Mars. The question is how like or unlike terrestrial forms of life they are and what plants or animals are capable of surviving in the extremely tenuous and cold atmosphere with its negligible oxygen content. Experiments, at least, confirm the possibility of life in conditions closely resembling those on Mars. Moreover, tests with meal beetles and tortoises indicate that a low oxygen content is in itself a good protection against the effects of cold.

In 1964 Mariner-4, a 260-kilogram (620-pound) probe, was launched from Cape Kennedy on a distant voyage to Mars. On the way it made some successful measurements of the intensity of chromosphere flares on the sun and transmitted the data earthwards. It studied the nature of solar radiation and established, among other things, that the sun emits electrons. In short, it continued the exploration of outer space begun in 1959 by the Soviet Lunas and later continued by the Venus-1, Mars-1, Zond-1 and Zond-2 probes.

On July 15, after travelling a huge distance involving some 40,000 collisions with cosmic dust particles, several trajectory corrections and telemetering link-ups with ground stations on earth, Mariner-4 came to within 9,000 kilometres of Mars. The instruments were made ready for the first close-up photographs of the planet. The sensitivity of the antennae of earth-based stations was sufficient to obtain pictures of a clarity and fineness of resolution far superior to those obtainable with the best of telescopes. The first part of the Martian surface to be caught in the camera's eye was the Elysium desert.

Hours of agonizing suspense followed. Slowly, line by line, the picture unfolded on the television screens. To reduce interference to the lowest possible level the scientists had decided to adopt a scanning rate of 8 hours 35 minutes. At first the signals were contradictory and it was hard to tell whether the transmission was proceeding normally. The magnetometer and radiation counter were operating clearly. But finally the first picture was received. On the following day it was reproduced by newspapers all over the world. Altogether 21 pictures were taken and their quality was good, especially those of the Martian desert Amazonis. Now, thanks to Mariner-4, we know that Mars has no radiation belts and its magnetic field is at least ten times weaker than the earth's.

SYNTHETIC GRAVITY

The bellbar crashes to the floor and the weight lifter walks dejectedly away. A humiliating defeat, and all because he had to lose weight to become lighter than his opponent. And losing weight means losing strength. In outer space it would be perfectly simple as there would be only one weight category, zero-weight!

Some astronauts say that weightlessness gives a feeling of exhilaration. Perhaps, but a price has to be paid for it, and sometimes it may prove exorbitant.

Synthetic gravity is one of the major concerns of space ship designers. Rotation of the ship would produce a good substitute in the shape of centrifugal force. Several requirements, however, would have to be met. The cabin should be far enough away from the axis of rotation, otherwise a body's weight would vary greatly in moving from one place to another. The angular velocity of rotation should not be too great, as with rapid rotation the paths of moving bodies tend to curve.

There are many plans for rotating space ships. According to one of them the vehicle separates in flight into two pieces, which are joined by ropes several hundred feet long. The whole system is then made to revolve about the common centre of gravity. Artificial gravity need not, of course, be equal to terrestrial gravity. This could even be fun; anyone could beat Yuri Vlasov's world weight-lifting record.

COSMIC WIND

Sails bellying out, a space ship races along through the endless depths of the universe. No motors or fuels, and none of the difficult problems associated with them. Only sails.

What is this? A dream? Yes and no. There is no such ship, of course, but the concept is more feasible than that of photon rockets. It is simple enough. There are "winds" blowing in the universe, but they are winds of light rays. And, like winds on earth, they can drive ships. The phenomenon is known as the pressure of light. From the point of view of the corpuscular theory of light, it is simply the result of the bombardment of a surface by light quanta, or photons. The pressure depends, of course, on the way in which the photons react with the surface; whether they are reflected and rebound as from a mirror or are absorbed as by a black body. In the latter case the pressure is least.

According to calculations carried out by James Clerk Maxwell, the pressure of sunlight at the surface of the earth on a bright sunny day equals 0.4 milligrams per square centimetre of black-body surface. You may think this is a negligible force that could hardly propel a space ship. But we must not forget that in outer space there is practically no friction or "drag". Besides, there is nothing to prevent the astronauts from raising gigantic sails.

The experimental demonstration of the pressure of light was carried out in 1901 by Professor P. N. Lebedev of Moscow University. At the time his experiment was a marvel of precision and ingenuity. Today, of course, it can be carried out in any physics laboratory.

SOLAR SAILS

Any attempt to make use of the solar wind to drive a vehicle on earth would be doomed to failure, if only because the sails needed to catch the wind would have to be much too big and cumbersome for a terrestrial vehicle. But in outer space, where there is no friction or atmospheric drag to oppose motion, even the tiny force exerted by light is sufficient to move a vehicle. One has but to hoist a sail and go with the wind. The reserves of solar fuel are inexhaustible, it does not have to be carried on board, and a sailing space ship could have more passenger accommodation and a greater instrumentation payload.

One of the first men to realize the possibility of sailing a space ship in the solar wind was Friedrich Tsander, who published several papers on the utilization of the pressure of light for interplanetary travel.

A solar sail would not be made of canvas, of course. It would be a large screen of highly polished aluminium foil or silvered plastic to reflect light well. In the days of sail ships the manning of the sails required considerable skill, and an experienced captain could reach a destination much faster by manipulating them ably. Space captains will also have to learn the art.

Although the first space clipper is not even on the drawing board, the data required for controlling its sails has already been tabulated and graphed. It has been calculated, for example, that assuming an acceleration due to sunlight of 2 mm/sec^2 at the orbit of the earth, it would take 164 days to reach Venus and 322 days to reach Mars.

What sized sail is needed to undertake such a trip? Assuming the space ship weighs 500 kilograms without the sail, the sail must be 500 metres in diameter. Technologically this is quite feasible.

The sun is a powerful source of corpuscular radiation which in active periods may increase to "gale" force 70 times stronger than the constant solar "breeze". Perhaps future astronauts embarking for other planets will be seen off with the old wish: "A fair wind to you!"

SOLAR BATTERIES

Legend has it that twenty-two centuries ago Archimedes set fire to Roman vessels by reflecting sunlight onto them with hundreds of parabolic mirrors. Nowadays sunlight is used to generate electricity in silicon elements. A semiconductor photovoltaic cell consists of two highly purified crystals of silicon to one of which is added a trace of arsenic or antimony (it is said to be doped with arsenic or antimony); the other is doped with boron or indium. Under the action of solar light the first crystal becomes a "donor" and gives off electrons. The second becomes a receptor of the charged particles. But a flux of electrons is in fact an electric current. The battery is working.

Suppose it were possible to build, somewhere in the sun, a single sufficiently large solar battery, say of a million square kilometres! Even at the present relatively low efficiency of photovoltaic cells (about 10 per cent) such a battery would produce more power than all the world's power stations put together. Many ambitious problems could then be solved.

However, a solar battery requires extremely pure silicon and so far it is simpler and cheaper to build several huge electric power plants of any type than to purify enough silicon for a single solar power plant of comparable size. In addition, strange as it may seem, solar batteries are susceptible to heating. Their efficiency, which is not very high in any case, drops by 0.6 per cent for every extra degree.

Scientists are now looking for more suitable substances than silicion. Gallium arsenide, for example, is not so susceptible to changes in temperature. Another idea is to remove the hottest part of the solar spectrum, the infrared, so as to get more light with less heat.

SPACE FOOD

"A real, voracious appetite ... appears after physical exercise, as after a chase or a hundred-mile trip by post-chaise," Chekhov wrote.

Amundsen had dog teams to carry food supplies during his famous trek to the South Pole. When the food ended the explorers ate the dogs.

The problem of food is an important one for space travellers, with added difficulties. For one thing, how does one go about eating in outer space? At first it was not known whether it would be at all possible to swallow food. Perhaps in the absence of gravity food just will not pass into the stomach? Or perhaps a careless movement will bring it up again?

These fears proved unfounded. Peristalsis, the waves of contractions that pass along the walls of the gullet, stomach and bowels, drive the food on in the natural way.

What about a man's appetite in space? Gagarin's flight could not solve the problem. His 108 minutes in flight was not long enough for him to get hungry, although he did take food as a part of his flight programme. Titov, however, had time to get hungry and he ate not just as an experiment but because he wanted to.

In conditions of weightlessness it is impossible to pour a glass of water. Dry food scatters in particles and a roasted chicken could fly about. Food must therefore be introduced into the mouth from a closed vessel, without resorting to such implements as spoons and forks. Liquids must be sucked through tubes.

But a liquid diet is inadequate, and so food is packed in tubes to be squeezed straight into the mouth.

More conventional food was provided on later flights. Popovich and Nikolayev, for example, enjoyed a menu of cutlets, roast meat, chicken, tongue, meat purée, fish-cakes, caviare sandwiches, jerked roach, oranges, lemons, apples and sweets. The only difference from restaurant service was that all dishes were prepared in bite-sized pieces that could be popped straight into the mouth.

The problem has been solved for short flights in near space. But what about prolonged flights? One cannot expect healthy men with good appetites (which, it appears, are improved by conditions of space flight) to be satisfied with soft foods squeezed out of tubes that one doesn't even have to chew. Yet a trip to Venus will take several months, and Venus is the closest planet. And there are no restaurants or snack bars on the way. The food problem for distant flights must be solved in the space ships themselves. One of the simplest things would be a vegetarian diet. Plants can be grown in a space vehicle. Not the higher plants, which are too fastidious and require terrestrial conditions, but algae. These evolve a great deal of oxygen and some of them are capable of increasing their weight sevenfold in 24 hours. They can synthesize large quantities of fats, proteins, carbohydrates and vitamins from a nutritious medium containing nitrogen. Algae are a boon not only to space ships like the Vostok but even to such a space vehicle as the earth.

The most suitable alga is chlorella, a unicellular green fresh-water weed which thrives remarkably on light, using it to produce nutritious substances. It does not demand only sunlight but can use electric light as well. Chlorella can assimilate 50 per cent of the incident solar energy, as compared with a maximum of 13 per cent for the higher plants. Chlorella is in fact a kind of solar battery.

Under good conditions chlorella yields up to 50 per cent of protein (the best beans yield only 30 per cent, and wheat, 18-24 per cent). It synthesizes fats and carbohydrates and contains the whole gamut of vitamins: A, B_1, B_2, B_6, B_{12} C, D, K, etc. One hundred grams of dry matter contains a man's daily ration. Chlorella also evolves oxygen. Its rate of growth is staggering, and it can increase its mass 8-10 times in one day, yielding 70 grams of dry matter, that is, food, per square metre of surface. Seven hundred kilograms per hectare. Ground plants yield a maximum of 110 kilograms.

But in a space ship there is not enough space to sacrifice many square metres to chlorella. This, however, turns out to be no problem! Several goldfish with small phials containing luminiferous substances attached to their tails swim about in a thick chlorella soup. They feed on the chlorella and mix it. Sufficient light for metabolism reaches practically every single chlorella cell from the phials.

Such chlorella plantations were suggested by the Japanese scientist Nakamura.

There still remain some vague aspects to the problem. Firstly, there are indications that algae may evolve some harmful substances. Secondly, it is not clear how algae will be affected by cosmic radiation. Lastly, there is the psychological aspect of a diet of algae day in and day out for months and months. Whatever attempts are made to present chlorella in different forms, whether as soups, steaks, pies, sweets or drinks, it may get on one's nerves in the end.

It has been suggested that a chlorella diet could be supplemented by animal plankton, which is suitable for eating and can itself be used to consume the cellular tissue not digested by man.

But spacemen will want meat. Maybe broilers are the answer? Algae is an excellent food for chickens, which also eat egg shells and powdered bone.

It is clear that, important as the food problem is for space flight, only the first steps have been made towards solving it.

PIONEERS OF LIFE

Round and oblong, colourless and coloured, sometimes growing with a cold light, they surround us everywhere and penetrate into places man can never reach. They work for us in the great chemical factory of the soil, they dutifully scavenge to keep the land and sea clean for us, and they also creep up unnoticed to deal lethal blows.

You have probably guessed that we are speaking of bacteria.

Microscopic animals were the pioneers of life on earth. They are the most likely inhabitants of all other planets where life is to the smallest degree possible. Bacteria are hardy and unfastidious and they can live where no other forms of life are possible.

When Soviet scientists launched the first rocket to plant a pennant on the moon they also took steps to prevent contamination of the moon with terrestrial microorganisms. Failure to do this could result in irreparable damage for science, as with germs of terrestrial life on it the moon would cease to be the virgin land it was. And if there is life of any kind there it could well be overrun by terrestrial forms in the struggle for survival. It is extremely difficult to prevent terrestrial forms of life being accidentally transferred to other planets. Equipment and clothing can be sterilized, but what about the human body, and the digestive tract?

An elaborate systems of defences protects us from microbes. Immunity helps us to beat back their daily attacks. But sometimes they break through an organism's defences. This is true of plants and animals alike, despite the millions of years spent in building up immunity. Microscopic animals on other planets may prove deadly enemies to man and steps must be taken to protect future astronauts from them.

Microbes may be brought back to earth by the instruments that will be sent to probe other planets and returned for analysis. It is therefore first necessary to study the microflora of other planets at a distance. Automatic laboratories are being designed that will be equipped with microscopes and other instruments for chemical and biological research and for telemetering their findings to earth. Such probes will analyze soil, atmosphere and water samples to detect and study the bacteria inhabiting them.

Is it worth populating the moon, Mars, Venus and other planets? The final say rests with the space microbiologists. It is for them to decide what microorganisms are best suited for this. Possibly, after mastering the mysteries of heredity, they will produce artificial microorganisms. These pioneers of terrestrial life may one day be the first settlers on other as yet lifeless planets.

LANDING PROBLEMS

It is one thing to reach another planet and quite another to land on it. In fact, landing may prove to be the most difficult part of a flight to Venus, Mars, Mercury or Neptune. No two planets are alike, and landing procedures must consequently vary. Our greatest interests, after the moon, are Venus and Mars. They are not only the closest planets to us but, like the earth, they have atmospheres whose drag can be utilized in landing. Re-entry through an atmosphere has been thoroughly studied. The return to earth of artificial satellites and manned space ships were rehearsals. They were preceded by a great many tests in wind tunnels. Similar preliminary tests will have to be carried out before a landing on Mars or Venus is attempted.

On earth it was simple enough. The composition and density of the upper atmosphere are well known from information collected by geophysical rockets. But how can one test landing techniques for other planets? Evidently it is necessary to produce an artificial Martian or Venusian atmosphere. Experts in planetary physics can tell us its approximate composition. The necessary gases can then be mixed in the necessary quantities in a special tank, brought to the required pressure and humidity—and we have a Martian or Venusian atmosphere. All that remains is to place a model of a space ship in the tank and connect it with a wind tunnel. Compressors are switched on and . . . 70 million kilometres from Mars a landing device hurtles through a "Martian" atmosphere, "brakes", "descends", and finally "lands".

Such experiments have not yet been carried out, but the time is not far off when scientists will be able to say that the conditions for landing in a Martian or Venusian atmosphere have also been thoroughly studied.

As for the other planets, a landing on Mercury will probably be much like a lunar landing, while the giant planets Jupiter, Saturn and Neptune present problems of their own. By the time man is ready to visit them, however, the landing methods will surely be ready.

FIRST STOP IN SPACE

Since the time when ape turned into man, some 400,000,000,000 representatives of *Homo sapiens* have walked on earth. However far their dazzling flights of fancy might have soared, they remained captives of the earth. This did not worry them very much, however, as they loved their planet.

On January 2, 1959, for the first time in human history, an object thrown up from the earth did not return. Instead it was destined to revolve forever around the sun.

Two hundred and fifty-five days later, on September 14 of the same year, the first terrestrial body fell on another world, the moon. The impact was evidently great enough for Luna-2 to burrow deep into the lunar soil, and future moon archaeologists will probably find and identify it by the pennant it carried.

Man is, of course, too delicate an organism to undertake a crash landing and he must devise a means of alighting gently on the moon's dusty or spongy surface.

Many projects have been suggested, some of them quite fantastic. One idea is to use wings to glide down. But where is the air or other gas to support them? The moon has no atmosphere, to be sure, but it has dust. A space ship will skim over its surface and incline the nozzle of its rocket engines towards the ground. The powerful jet of exhaust gases impinging on the ground will raise clouds of dust and gas, which will provide the necessary support for the wings. This cushion will, of course, disperse in a few moments, but it will last long enough for the vessel to land softly. The practicability of this project has yet to be tested.

A more feasible project is for a space ship to go into orbit around the moon, brake gradually and descend with nozzles pointing downward to offset the moon's gravitational pull. By manipulating the exhaust jet it should be possible to land the rocket as delicately as a butterfly on a swaying flower.

Landing on the moon will be one of the greatest human accomplishments of the third quarter of the twentieth century.

WALKING ON THE MOON

The lunar relief will probably appeal to the most enthusiastic of mountain climbers. They should be forewarned, however. They will not find "larger animals and more beautiful trees than on earth", as Pythagoras wrote. If they turn one cheek to the sun it will literally smoulder (at a temperature of plus 120°C), while the other will freeze (at minus 150°C). Protective shields will be necessary to ward off meteorites bombarding the moon.

A hiker on the moon will have to take food and water with him. It will be harder to get water there than to photograph the far side. There are areas with temperatures ranging from —75 to +38 degrees (about the same as in the Siberian autonomous republic of Yakutia), and it is said that there may be water in crevasses in these parts, but we don't know for sure.

Lunar explorers will be well advised not to pitch camp in the neighbourhood of the crater Alphonsus, where Professor Nikolai Kozyrev discovered volcanic processes in 1958. He who does not follow this advice may quickly change his mind when gases begin to erupt at the rate of up to 100 cubic metres per second (a very conservative estimate).

But if some cross-country enthusiast does shoulder his knapsack and trek over the unpeopled lunar country he will be rewarded with:

exciting climbs up lunar mountain ranges with peaks rising as high as 9,000 metres;

remarkable landscapes with sharp colour contrasts and a complete absence of penumbra and suffused light;

beautiful "earthlit" nights much brighter than the moonlit nights we know on earth. The sight of the bluish disk of the earth will surely make the traveller homesick.

The tourist on the moon will doubtlessly have a lunar map with him, but he must be careful in using it. Even today scientists stubbornly refuse to shatter the illusions of their medieval colleagues who regarded the darker areas on the lunar disk as seas. Such is the force of tradition that scholars wished to think of the moon as having been created in the likeness of the earth. This is seen in the names of lunar seas (or maria, as they are called), mountain ranges and craters. In the 17th century Johannes Hevalius, an astronomer from Danzig, assigned geographic names to many lunar features. Thus there appeared on the moon the Apennines, Carpathians, and the Caucasus. These names did away with some of the inconveniences that could arise if features of the lunar relief were named after people. Nevertheless, one

Spanish astronomer renamed the Apennines the St. Michael's range and the Aegean Sea the St. Ursula Sea.

However, the Italian Jesuit astronomer Giovanni Riccioli restored Hevelius's names and gave to the more conspicuous smaller features the names of famous philosophers and scientists, substituting, for example, Plato (instead of St. Athanasius), Ptolemy (instead of St. Margaret) and Galileo (instead of St. Genevieve). Riccioli did make one exception; he merely dropped the St. from the name of St. Catharine to leave the name of the woman he loved. He named a huge crater 235 kilometres in diameter with a central peak after his friend Grimaldi, and gave his own name to a crater near the edge of the moon's disk.

The lunar seas are vast plains whose darker colouring gives the moon the face-like appearance we see on a bright moonlit night. And the lunar traveller might remember during his trek that Mare Tranquilitatis (Sea of Tranquility) is the left eye of the moon's face, Mare Imbrium (Sea of Rains) is the right eye, Mare Serenitatis (Sea of Serenity) is the bridge of the nose, Oceanus Procellarum (Ocean of Storms) is the right cheek and Mare Frigoris (Sea of Cold) and Mare Crisium (Sea of Crises) are the eyebrows.

Sinus Aestuum, Lacus Somniorum, Palus Epidemiarum. Fanciful, exciting names. But they merely denote greyish transitional features lying between the darker "seas" and lighter "lands".

The origin of the moon's craters is still being disputed by scientists. Some claim that they are extinct volcanoes and that the bright rays spreading out from Tycho and several other craters are solidified lava streams; others declare them to be scars left by the impact of meteorites. They may even have been dug by selenites, as the heroes of one of Jules Verne's novels claimed, for protection against the direct rays of the sun.

One of the moon's mysteries was solved with the photographing of its far side, which cannot be seen from the earth. Now to the names of Archimedes, Copernicus, Aristotle and other great men on the map of the moon there have been added the names of Jules Verne, Giordano Bruno, Maxwell, Lomonosov, Edison, Popov, Hertz, Lobachevsky, Pasteur, Curie-Sklodowska, Tsiolkovsky, Tsu Chung-chih and Kurchatov. And the Sea of Moscow, or Mare Muscovitatis in traditional lunar nomenclature, is a suitable end for our trek of the moon.

THE SUPREME JUDGE

Time is like an eternal mighty ocean, with the light ripples of seconds, the white horses of minutes and the waves of years and centuries. The mighty breakers of millennia roll noiselessly by like huge dinosaurs. Planets and stars evolve, men and ideas change. Time is the eternal witness of the passing history of everything living and inanimate.

There was a time when man did not keep close track of its passage. Day and night, summer and winter were sufficient for him. But as man progressed he learned to value and count time. He began to measure time with sundials, hour-glasses and clepsydras. Then he invented pendulum clocks, spring-wound clocks and watches. At first these had only a single hour hand; seconds, and even minutes, were of no interest. Soon, however, travellers on land and at sea realized the need for the precise measurement of time. Knowing Greenwich time, one could determine one's position. Greenwich time was kept by very accurate clocks called chronometers. In our day a second is a very long period of time indeed. People now study processes that last only thousandths and millionths of a fraction of a second. There is no way of halting time but images of fleeting phenomena can be recorded, with the inventions of high-speed photography and oscillographs.

Time passes and no one can keep up with it. What about riding astride a beam of light? Einstein predicted, from his theory of relativity, that travel at speeds approaching that of light is accompanied by the phenomenon of time dilation. Moreover, the passengers of a sub-light space ship could claim that they were actually travelling faster than light. Let us assume that it takes light from some star 20 years to reach the earth. If a space ship travels at 240,000 km/sec, that is, 0.8 the velocity of light, it will take 25 years to reach the star, and that is what people on earth would see according to their calendars. But inside the space ship the crew would find that only 15 years had passed. Which means that fathers could conceivably grow younger than their children, for not only does time dilate but all vital processes take place at a correspondingly slower rate.

Time is inexorable. It sweeps aside the senile, decayed and outdated, clearing the way for the new and progressive. The supreme judge, time alone, decides who is to become immortal and who is to be forgotten. It belongs to the forward-looking, to those who dream and work and build the future. As Vladimir Mayakovsky wrote, "The future will not come of its own accord. We must work for it."

TO THE READER

Mir Publishers would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make. Our address is: 2, Pervy Rizhsky Pereulok, Moscow, U.S.S.R.

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